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Survey of Biofouling on Australian Navy Ships: Crustacea; Isopoda and Amphipoda; Caprellidea

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Maritime Platforms Division
Defence Science and Technology Organisation

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ABSTRACT

Biofouling on ships not only impedes ship movement, but also allows species from one location to be transported to a site that it would normally not inhabit. In many cases, these exotic species have had deleterious effects on the native species, sometimes resulting in the extinction of less competitive native species. In an attempt to gain some understanding of the environmental threat posed by biofouling from vessels arriving from overseas, Defence has undertaken a survey of the biofouling present on Royal Australian Navy (RAN) Ships that have returned from overseas duties. Within the crustacean order Isopoda, several species are known to have been translocated, as biofouling, on early wooden ships. The two most common species found in the DSTO/RAN study were *Paracerceis sculpta* and *Sphaeroma walkeri*, both previously reported as introduced species and now having a wide distribution, both in Australia and world wide. Other species that were recorded in the survey were *Neosphaeroma laticaudum* and *Cymodoce gaimardii*. Some of the specimens received were too immature to allow identification to species level; these were identified as belonging to the following genus; *Cymodocella*, *Ischyromene*, *Argathona* and *Cirolana*. Caprellid species identified from biofouling samples taken from RAN ships were; *Caprella penantis*, *C. californica* and *C. equilibra*. *Paracaprella pusilla* was also identified in this survey.

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Executive Summary

The Royal Australian Navy's increased awareness of its impact on the marine environment has resulted in an attempt to try to identify and address environmental issues pertinent to Navy vessels and their operational procedures. One of the most contentious issues is the translocation of exotic species into Australian waters. In many cases, these exotic species have had deleterious effects on the native species, sometimes resulting in the extinction of less competitive native species. The underwater hulls of modern ships are largely protected from fouling by use of antifouling paints, but unpainted niches and hull fixtures and fittings are still prone to fouling colonisation. Once a vessel is in the water for over 2-3 weeks it can begin to accumulate microalgae and invertebrate biofouling, and depending on the amount of time it remains in the water, this biofouling becomes an intricate microcosm supporting a variety of organisms that potentially accumulate from each port the vessel visits. This allows species from one location to be transported to an environment that it would normally not inhabit, and poses a risk to the native flora and fauna. Defence has undertaken a survey of the biofouling present on RAN ships that have returned from overseas duties. Organisms taken from these ships are identified in an attempt to assess the risk of exotic species entering Australian waters as a direct result of translocation by Navy ships.

This report focuses on isopods and *caprellid* amphipods. Isopods are mobile, bottom dwelling small crustaceans that are sometimes known as marine pill bugs; caprellid amphipods are small pericarid crustaceans that live as epibionts on a variety of substrates, and are commonly known as skeleton shrimps. The two most common species of isopods found in the DSTO/RAN study were *P. sculpta* and *S. walkeri*, neither of which is native to Australian waters. Both have previously been recorded in Australian waters and are well established as introduced species with a cosmopolitan distribution, both in Australia and worldwide. Other species that were recorded in the survey were *N. laticaudum* and *C. gaimardii*, both species previously recorded in Australian waters. The most common species of caprellids were *C. equilibra* and *C. penantis*. Two other species, *C. californica* and *P. pusilla* were also recorded in this study. The latter was especially prevalent in biofouling samples taken from vessels based in Northern Queensland waters. The observations support the view that biofouling on ship hulls continues to be a potential vector for the translocation of marine species, including small, motile crustaceans.

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Luciana Montelli graduated BSci (App. Chem.) from Royal Melbourne Institute of Technology. She joined DSTO, Maribyrnong where she became involved in the formulation of insensitive munitions and the synthesis of energetic material, and assessment of the viability of using bioremediation for the treatment of explosives contaminated soil. Further study, involved a Grad Dip (Biotechnology) from the University of Melbourne, and involvement in trials conducted at Innisfail, to determine the possibility of using bagasse as a means of bioremediation for TBT wastes. Currently she is involved in providing environmental support for the RAN, and is conducting a project to identify and classify marine fauna found in biofouling on RAN vessels. She completed a BSc (Marine Biology) from the University of Melbourne in 2007, and is currently undertaking an Honours program.

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Since 1977, after completing BSc (Hons) and MSc degrees in marine biology at the University of Melbourne, John Lewis has worked as a scientist in the Defence Science & Technology Organisation, with primary research interests in marine biofouling and its prevention, and the effects of RAN activities on the marine environment. John currently heads the Environmental Compliance and Biotechnology Group, within the DSTO Maritime Platforms Division, and leads a team investigating new, environmentally acceptable methods of biofouling control, biofouling and marine pest management, environmental compliance of naval vessels, and other environmental aspects of navy operations.

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1. Introduction

The role of human activities in the translocation of organisms from one corner of the earth to the other cannot be understated. Over the last five centuries, the redistribution of marine organisms across vast oceans to environments that were inaccessible to them by natural means can be almost entirely attributed to shipping-related activities and commercial aquaculture (Carlton & Hodder, 1995). Reviews carried out by Carlton and Hodder (1995) identified three major processes that altered the natural distribution of marine species: the digging of canals, most notably the Suez and Panama, inadvertent transport on ships, and deliberate introductions.

The invasion of species facilitated by shipping has done, in years, what it took nature hundreds of thousands of years to accomplish. It is difficult to gauge the true extent of this invasion phenomenon, as most of the early shipping pre-dates any comprehensive biological surveys on historically travelled sea routes (Carlton and Hodder, 1995) and the true geographic origin is uncertain.

The first invasion of Australian waters by exotics is thought to have occurred around the mid-1800s at the time of the gold rush, although species could have arrived with the early European explorers and during the European colonisation of Australia. The exotic bryozoan species, *Electra pilosa*, was first reported in Port Phillip Bay, Victoria, in 1862, but the introduction of the European shore crab, *Carcinus maenas*, recorded from Port Phillip Bay in the late 1890s, was regarded as the first 'pest' species (Thresher et al, 1999). Over the next century, an additional 62 exotic marine species were recorded (Pollard and Hutchings 1990), many of which would have been translocated as fouling on ships' hulls (Allen, 1953). For example, in 1953, living specimens of the three barnacle species *Balanus amphitrite albicostatus*, *B. tintinnabulum* and *B. tintinnabulum volcano*, whose distribution was known to be restricted to the Japanese sea, were found on vessels arriving in Australia from Japan (Allen, 1953). Literature reviews and field sampling during 1995-1996 identified 99 introduced and 66 cryptogenic species, totalling 165 species, as present in Port Phillip Bay (Thresher et al, 1999). This may still be an underestimate, due to bias in sampling and the incomplete taxonomic knowledge of some invertebrate groups (Thresher et al, 1999).

Ship's ballast water is a well-documented vector for the translocation of marine species. On uptake, ballast water can contain a diversity of plankton and nekton that, depending on the length and temperature of the voyage, may survive lengthy voyages (Williams & Griffiths, 1988). With ballast water, most of the organisms in the plankton are in the larval stage, making it difficult to identify them by classical taxonomic means, and new technologies such as gene probes are proving useful in the identification of planktonic species. National and international regulations have been introduced to manage ballast water to minimise the risks of translocating species (Allen, 1953), but biofouling has, until recently, been overlooked. In Australia, however, this problem has been recognised, and management practices are now being developed to manage this risk.

All underwater surfaces, including ship hulls, are prone to colonisation by marine organisms, collectively known as biofouling. The hulls of modern ships are protected from biofouling with antifouling paints, but these do not fully eliminate fouling, which can occur on ineffective or depleted paints or on unpainted niche areas and hull appendages (AMOG, 2001). Of the non-indigenous species reported from Port Phillip Bay, 77% were considered to have been possible introductions by ship biofouling (Thresher, Hewitt & Campbell, 1999).

The major groups of fouling species are; microalgae, macroalgae, sponges, hydroids, tubeworms, molluscs, barnacles, amphipods and other crustaceans (including isopods and caprellids), bryozoa and ascidians (Lewis, 1998). In this report we will focus on the crustacean groups, Isopoda and Caprellidea.

Isopods are known to inhabit a variety of environments, and are known to occur within the biofouling associated with the hulls of ships (Woods Hole, 1952), as well as the wood pilings in the harbour. In many cases the isopods are epizoic, dwelling on sponges, or sheltering in the deserted tests of barnacles attached to the hull, common in ship biofouling. This type of behaviour increases the chances of isopods being translocated, along with biofouling, from one port to another by these vessels, and becoming established in areas where they are not native.

Caprellid amphipods are small peracarid crustaceans distributed along the world coasts. They usually live as epibionts on a variety of substrates, and are known to inhabit areas from the littoral zone to a depth of 4790 m (Sconfiatti, 1995). Many are commensal with other invertebrates such as echinoderms, hydroids and bryozoans (Guerra-Garcia, 2001a). Most caprellids are not habitat-specific, occurring on sponges, hydroids, alcyonarians, bryozoans and various sea grasses and algae (McCain, 1965).

Caprellid amphipods feed by browsing, filter-feeding, predation, scavenging and scraping. The manner in which food is acquired is dictated by the presence or absence of plumose setae on the second antenna (Caine, 1977). Species that have plumose setae depend largely on filtering and scraping periphyton to obtain their food, while species lacking this type of setae, rely on predation. Studies carried out on filter feeders found together showed there to be no feeding overlap due to different species feeding on different sized particles, or the species filtering varying heights from the substrate. Any species that share the same sized particles and heights employ different feeding mechanisms (Caine, 1977).

Many caprellids show little or no selectivity for specific substratum, and are known to colonise a wide variety of substrata. They therefore have a wide distribution potential, particularly with the presence of strong ocean currents, which have the potential to transport suspended or floating substrata over large distances (Thiel, 2003). More consideration should be given to surface water temperature as an important factor determining the distribution of littoral caprellids, with a decrease in species richness as we move towards both northern and southern latitudes (Thiel, 2003).

2. Order Isopoda

The order Isopoda Latreille, 1817, contains at least 10,000 species, most of which are marine but also with a few freshwater and terrestrial species (Pechenik, 2000). The distribution of some species has been aided by their lifestyle or habitat preference. For example, some species of the family Limnoriidae and *Sphaeroma* are wood borers, and their present geographic distribution can be attributed to early commercial shipping (Kensley, 2001). Isopods are known to brood their eggs and young, limiting their dispersive capabilities, but many species have been able to overcome this problem by associating with encrusting sessile invertebrates that are transported as biofouling on the hulls of ships.

Isopods tend to be small, from 0.5 cm to 3.0 cm in length, and have a characteristic dorso-ventrally flattened body, without a carapace. There are some examples of extremely broad and flattened bodies, but these are uncommon and represent a derived condition. The first thoracic somite is always completely fused with the head, leaving only seven free somites of the thorax. They have uniramous first antennae, which have only one flagellum. The seven remaining pairs of thoracic appendages are mostly all similar and used for locomotion or are sub-prehensile in nature. The compound eyes, if present, are not on movable stalks, but are sessile or raised on immobile processes of the head (Hale, 1929). The coxal plates are formed from the expanded coxae of the legs, which form the lateral extension of the segments via the fusion with the thoracic somites. The telson is fused with the sixth abdominal somite, resulting in five abdominal segments and an abdominal-fused-telson segment, and in other families, further fusion can lead to a decrease in the number of abdominal segments.

2.1 Suborder Flabellifera (suborders Cymothoida and Sphaeromatidae)

The suborder Flabellifera Sars, 1882, comprises a large paraphyletic group, and is the second largest isopod suborder. All of the fouling isopods identified in this study are members of suborder Flabellifera, and were traditionally classified into three different families: the Cirolanidae, the Corallanidae and the Sphaeromatidae. It has been suggested that instead of Flabellifera, 4 suborders; Valvifera, Cymothoida, Limnoriidea and Sphaeromatidae be used to better reflect their phylogeny. In considering the suitability of maintaining the suborder Flabellifera, it is now proposed that Flabellifera be replaced by the two suborders Cymothoida and Sphaeromatidae with the implementation of the new suborders, Tainisopidea, Phoratomidea and Limnoriidea, as well as the elevation of Cirolanidae to superfamily rank (Wagele, 1989; Brandt and Poore, 2003).

Members of the family Cirolanidae are cosmopolitan, found on sandy beaches, rocky shores, coral reefs, and on shelf and slope environments. Within Australia, species commonly have distributions that extend along the south-eastern (New South Wales and Victoria) or eastern (Queensland) coasts (Bruce, 1986). Members of the family Corallanidae are confined to tropical and subtropical regions.

The majority of the specimens recorded in this survey belong to the suborder Sphaeromatidae (Brandt and Poore, 2003). The Australian continent is noted for its abundance of this family of isopods with nearly 28% of sphaeromatid species found in Australia, compared to other regions (Poore, 2002). A common marine fauna in the Southern Hemisphere, inhabiting diverse benthic environments, the suborder Sphaeromatidae is typically found on rocky shores and in shelf waters around Australia (Holdich and Harrison, 1983). It can occur throughout a wide range of habitats from fresh water to brackish water, as well as high eulittoral levels to depths as great as 1800 m, though individual species tend to occur in specific niches to which they are restricted (Hurley and Jansen, 1977). In the intertidal zone sphaeromatids are most commonly found on or in burrowing wood, sand or mud, under stones, and in or among weed, especially algal holdfasts, bryozoans, sponges and tunicates (Hurley and Jansen, 1977).

3. Order Amphipoda

3.1 Suborder Caprellidea

The suborder Caprellidea White, 1847 emend, constitutes one of the four suborders of Amphipoda, and is unique in the reduction or lack of pereopods III and IV, and/or abdominal segments and their appendages (Takeuchi, 1993). The characters that distinguish caprellids from the other amphipod suborders are: the rounded head with ventral mouthparts, minute coxal plates, no more than three pairs of gills and two pairs of marsupial plates. The suborder Caprellidea consists of three families: Caprellidae, Cyamidae, and Phtisicidae.

Caprellids possess a long slender thorax and almost no abdomen. Their heads are well defined and they have two pair of antenna. They have a pair of enlarged grasping clawed appendages for grabbing zooplankton as it floats by. Their last two pair of appendages is modified for clinging to algae and colonial hydroids such as *Obelia*.

The eggs are contained in the marsupium of the female, which is formed by 2 pairs of oostegites on pereonites 3 and 4. The cleavage is superficial, and the embryo develops into the nauplius and then metanauplius within the egg and is grown to generally 0.4 mm to 0.5 mm in size when hatching out. Even though the hatched larvae are 1mm or less in length, they already exhibit external characteristics similar to those of the adult. The larvae stay in the marsupium until they are liberated at moulting of the mother (Arimoto, 1976).

Caprellids commonly live among algae, and the hydroids attached to the algae, growing under docks, on pilings, submerged lines, hoses and on rocks along the shoreline. They are carnivores that feed on the hydroid colonies to which they cling and on the microorganisms that float by.

As caprellids attach to algae, hydroids, bryozoans and other fouling epibiota, they are potential candidates for translocation on the hulls of ships. They are rare swimmers but may be taken into ballast water as tychoplankton. Although many species are apparently widespread, there is no suggestion that these distributions are artificial rather than natural. Most species of *Caprella* have a global distribution but can vary in morphology (McCain 1965).

3.2 Family Caprellidae

Most of the genera within the family Caprellidae, White, 1847 emend, have a well developed suture between the head and pereon, and bear paired long setae on antenna 2; two genera have a minute accessory flagellum on antenna 1. Although classically considered to be the most highly evolved free-living caprellideans, they retain a number of basic, corophioidean, characters. Protoaeginella is anomalous in having a 5-segmented abdomen bearing only rudimentary appendages (male) and setae (Laubitz, 1993).

4. Method

For the biofouling survey, a total of 32 in-water dive surveys were undertaken on 23 individual RAN ships and submarines between March 2003 and February 2005. The dives were undertaken by URS Australia, and took place at Fleet Base West (Garden Island, Cockburn Sound, WA), Fleet Base East (Garden Island, Sydney Harbour), HMAS Waterhen (Balls Head Bay, Sydney Harbour), HMAS Cairns (Cairns North Queensland) and, in one case, Dunedin, New Zealand. The 23 individual ships included 10 classes of ships. In preparation for each dive, the hull of each ship was assessed to determine the areas potentially most prone to fouling, such as the seachests, intakes, anodes, drydock support strips, rudder post and hinges, shaft A-brackets, rope guards and stern tubes, non anti-fouled sonar domes, non anti-fouled propellers and bosses, other voids and appendages (eg. Auxiliary propulsion units (APUs), uncoated log probes) (URS, 2006). The dive survey consisted of video transects over the entire hull length, still photography taken of any biofouling found on the hulls, followed by sample collections of representative patches of biofouling found at a set of pre-identified sites, as well as other opportunistic locations (URS, 2006). These samples were then preserved in ethanol and shipped to DSTO, Melbourne for sorting and identification.

In the laboratory, the samples were filtered using a buchner funnel and filter paper to remove the excess ethanol. The filtrate was then scraped into a plastic petri dish containing 20-30 mls of 10% glycerol and 90% ethanol solution. This was then placed under a microscope, and samples sorted firstly into broad taxonomic groups, and then into species where possible. Individual isopods and caprellids were re-examined with a stereomicroscope to enable identification and enumeration. Identification of other species and taxa is still in progress, so information relating to the associated species is not available for all samples. However, where known, this is given.

5. Results

5.1 Isopoda

Isopods were found in samples from 13 ships (Table 1) Known details of these ships are given in Table 2. In all, 9 different isopod taxa were identified. Of these, 4 were identified to species level. The remainder could only be identified to genus level because the specimens were either too immature or damaged. Details of taxa are discussed below.

Table 1. Identification of species found on RAN vessels.

HMA SHIPS (Class)	HOME PORT (Survey Location)	LOCATION OF SPECIMEN	DATE	SAMPLE ID.	ISOPOD Genus Species
<i>Adelaide</i> (FFG Frigate)	Western Australia (W.A.)	Rudder strop holes	10/7/03	G	<i>Sphaeroma walkeri</i>
				G2	<i>Cirolana sp</i>
		Rudder Post	10/7/03	A	<i>Sphaeroma walkeri</i>
		Stern Tube	10/7/03	H	<i>Sphaeroma walkeri</i>
		Transom	10/7/03	K	<i>Sphaeroma walkeri</i>
<i>Anzac</i> (FFH Frigate)	W.A.	Stern	21/5/03	AA	<i>Paracerceis sculpta</i> ♂2 ♀3
<i>Benalla</i> (Patrol Boat)	Cairns	DDSS	9/5/04	BE U	<i>Argathona sp</i>
<i>Canberra</i> (FFG Frigate)	WA	Masker belt guard	27/10/03	RAN-F	<i>Psuedosphaeroma sp</i>
<i>Darwin</i> (FFG Frigate)	W.A.	Port (P47-P37)	1/12/03	F	<i>Pseudosphaeroma sp.</i>
<i>Dechaineux</i> (Submarine)	W.A.	Bow shutters	1/8/03	AJ	<i>Neosphaeroma laticaudum</i>
(Mine-hunter Coastal)	Sydney	DDSS	24/11/03	N	<i>Sphaeroma walkeri</i>
<i>Ipswich</i> (Patrol Boat)	Cairns	DDSS	9/5/04	IR (FR)	<i>Sphaeroma walkeri</i>
<i>Manoora</i> (Amphibious Support)	Sydney	Keel strake DDSS	10/11/03	AJ	<i>Paracerceis sculpta</i> ♀
		Rudder	1/7/03	Sample 1	<i>Cymodoce gaimardii</i>
<i>Melville</i> (Hydrographic ship)	Cairns	Bilge Keel upper & lower	9/5/04	MK	<i>Sphaeroma walkeri</i>
		Rudder stock and rudder	9/5/04	MO	<i>Sphaeroma walkeri</i>
		APU & housing	9/5/04	MU	<i>Sphaeroma walkeri</i>
<i>Rankin</i> (Submarine)	WA	Recessed circular covers (fwd of APU)	27/10/03	R	<i>Sphaeroma walkeri</i>
<i>Shepparton</i> (Patrol Boat)	Cairns	Anodes	8/5/04	SX	<i>Sphaeroma walkeri</i>
<i>Sydney</i> (FFG Frigate)	W.A.	Rudder	17/8/03	D	<i>Sphaeroma walkeri</i>
		Propeller	17/8/03	K	<i>Cymodocella sp</i>
<i>Warramunga</i> (FFH Frigate)	WA (Dunedin New Zealand)	Transom	6/10/03	WRM009	<i>Ischyromene sp.</i>
<i>Westralia</i> (Under-way Replenishment tanker)	W.A.	Bow paint damage	1/8/03	AD	<i>Paracerceis sculpta</i> ♂
		Hull taper aft	1/8/03	J	<i>Paracerceis sculpta</i> ♀

[APU-Auxiliary propulsion unit; DDSS-Dry dock support strip]

Table 2. Ship movements prior to inspection and sampling.

HMA Ship	Inspection Location	Previous POC/working areas	Inspection Date	Isopod
<i>Adelaide</i>	FBW	Broome, FBW, Chennai, Singapore	11/7/03	<i>S. walkeri</i> <i>Cirolana</i> sp
<i>Anzac</i>	Fremantle	Middle East-via Phuket	NA	<i>P. sculpta</i>
	FBW	Fremantle	21/5/03	
<i>Benalla</i>	Cairns	Northern Australia	9/5/04	<i>Argathona</i> sp
<i>Canberra</i>	WA	Cairns, Brisbane, FBE	27/10/04	<i>Pseudosphaeroma</i> sp
<i>Darwin</i>	Fremantle	Middle East-via Seychelles, Diego Garcia	NA	<i>Pseudosphaeroma</i> sp.
	FBW	Townsville, Gladstone, Brisbane, Adelaide	1/12/03	
<i>Dechaineux</i>	FBW	Singapore, Darwin	1/8/03	<i>Neosphaeroma laticaudum</i>
<i>Hawkesbury</i>	Waterhen	Solomons, Hobart, Melb.	24/11/03	<i>S. walkeri</i>
<i>Ipswich</i>	Cairns	Northern Australian	9/5/04	<i>S. walkeri</i>
<i>Manoora</i>	FBE	Honiara via Townsville	10/11/03	<i>P. sculpta</i> <i>Cymodoce gaimardii</i>
<i>Melville</i>	Cairns	Northern Australian	9/5/04	<i>S. walkeri</i>
<i>Rankin</i>	WA	Adel., Pt. Wilson, FBE, Brisbane, Gladstone	27/10/03	<i>S. walkeri</i>
<i>Shepparton</i>	Cairns	Northern Australian	8/5/04	<i>S. walkeri</i>
<i>Sydney</i>	FBW	Falconer, Middle East	17/8/03	<i>S. walkeri</i> <i>Cymodocella</i> sp.
<i>Warramunga</i>	Dunedin	Darwin, Pearl Harbour, Noumea	6/10/03	<i>Ischyromene</i> sp.
<i>Westralia</i>	FBW	FBW, Broome, Christmas Is, FBW	1/8/03	<i>P. sculpta</i>

[POC = Port of Call]

Family Sphaeromatidae

5.1.1 *Cymodoce gaimardii*

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

***Cymodoce gaimardii* (H. Milne-Edwards 1840)**

Hale, 1929:286, Fig. 284; Poore, 2002: 251

Sphaeroma gaimardii H. Milne-Edwards, 1840

Type locality:

Australia (as Nouvelle-Hollande).

Distribution:

Queensland and Great Barrier Reef, Southeast and Southwest Australia (Hale).

Collection details:

HMAS Manoora, Sydney, 10/11/03, Sample 1 (Rudder).

Associated species:

None: the specimen was selectively sampled from the ship rudder.

Diagnosis:

The convex, suboval body is smooth and there are no large dorsal processes from any of the somites (Figure 1). The telsonic segment has the terminal notch deep and the median process large, apically truncate and reaching to the level of the acute lateral angles of the notch. The first three pair of legs are rather more robust than the others. The uropods do not reach to the end of the abdomen; the branches are subequal in length, with their apices obtuse or subacute. Length is 25 mm, but a small variety of this species also occurs.

The non-ovigerous female does not differ markedly from the male; the terminal notch of the abdomen is not so deep and the median projection is rounded (not truncate) apically (Hale, 1929).

Comments:

C. gaimardii is known as a Southern Australian species, and has been collected in Port Phillip Bay, Victoria, Encounter Bay, South Australia, and the Swan River estuary, WA. , and has also been reported from Tasmania and Gulf St. Vincent, South Australia (Hass & Knott, 1998).

HMAS Manoora is an amphibious class ship based in Sydney, where the survey was performed. Prior to the survey *HMAS Manoora* travelled to Honiara via Townsville.

The presence of *C. gaimardii* on *HMAS Manoora*, berthed at Garden Island, Sydney is not unusual, given the wide distribution of the species in Australia. Given that there were no associated species or biofouling with the isopod when collected, it seems unlikely that the isopod had colonised *HMAS Manoora*, but was more likely a transitory presence from an established colony in the harbour.

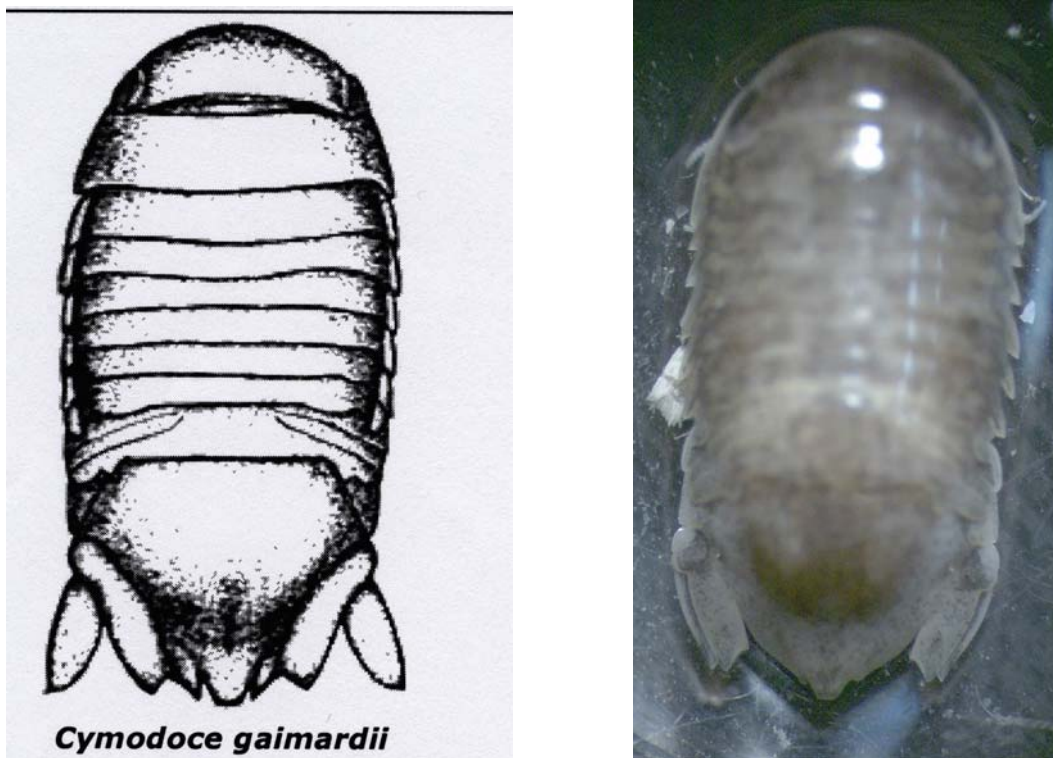


Figure 1. *Cymodoce gaimardii*; (from Hale, 1929: 286; Fig 284.), and a photograph of the specimen obtained from HMAS Manoora.

5.1.2 *Neosphaeroma laticaudum*

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Neosphaeroma laticaudum (Whitelegge, 1901)

Whitelegge, 1901, (reprinted in Hale, 1929: 274 Fig. 272.); Poore, 2002: 241

Synonym

Cassidina laticauda Whitelegge, 1901

Type locality:

Off Coogee, NSW, off Crookhaven River, NSW

Distribution:

Australia: 200 m bathymetric, (Lower East Coast, Southern Gulfs Coast), NSW, SA.

Collection details:

HMAS *Dechaineux*, Western Australia, 1/8/03, sample AJ (Bow shutters)

Associated species:

Barnacles: *Amphibalanus amphitrite*; tubeworms; (*Hydroides* spp.); didemnid ascidian.

Diagnosis:

The body is moderately convex from side to side, closely and minutely punctate, glabrous, smooth and glossy (Figure 2). It is very broad in proportion to its length, the ratio being 6.7:11. The cephalon is strongly deflexed in the front, three times as broad as long. The frontal margin is bisinuate, with a short median rostriform process, apically rounded.

The first pereon segment is equal in length to the cephalon and the basal antennal joints are combined. The second and third pereons are little more than half the length of the first: the fourth fifth, sixth and seventh gradually decrease in length; the fourth is half and the seventh one-sixth the length of the first.

The first pleon segment is a little shorter than the fourth segment of the pereon, the lateral margins are broad and evenly rounded. The pleon is much narrower than the pereon, and consists of two segments. The terminal segment is large, with a lateral pair of epimera-like processes and a tridentate distal border.

The telson is nearly twice as broad as long, and the upper surface is strongly convex and smooth. The eyes are oval, widely separated, lateral and prominent, and very dark brown in colour. The flagellum has ten articulations, and is shorter than the peduncle.

The mandibles are stout, the molar tubercle is broad and short, and the palp is three-jointed. The anterior maxilla with the masticatory lobe is somewhat narrow, and tipped with curved simple spines; the basal lobe has four unbranched filaments at its apex.

The posterior maxilla is three-lobed and the maxillipeds are slender, the palp consists of five joints, the anterior pair of legs is shorter and stouter than the posterior; the dactylus of all the pairs has a small secondary subterminal claw.

The pleopods are foliate; all except the last pair, which is densely ciliate. The uropods are short, with the mobile ramus minute. The outer branch of the uropods is only about half the length of the fixed endopod, which is somewhat scythe-shaped and reaches to the level of the end of the abdomen.

The exopod is incised postero-laterally, and the apex and outer margin are furnished with tiny teeth.

The colour is cream. Length: 21mm (Whitelegge, 1901).

Comments:

The identification of this isopod was difficult to confirm due to its immaturity, and the absence of some of the characteristics evident in an adult. However, it was identified as *N. laticaudum* by its smooth and glossy appearance and the broadness of its body, which was the same as the 6.7:11 ratio characteristic of *N. laticaudum*.

This species is known from the lower east coast of NSW and southern gulf coasts of South Australia. The species was collected off the submarine *HMAS Dechaineux* when berthed in Garden Island, WA. Prior to returning to WA, the vessel had visited only the ports of Singapore and Darwin, both outside the known distribution range for *N. laticaudum*, and the species is therefore considered unlikely to have been translocated to WA from either of these ports. The presence of only one, immature specimen suggests a proximal breeding colony, and that colonisation of the submarine was from an established colony in the Fleet Base West harbour.

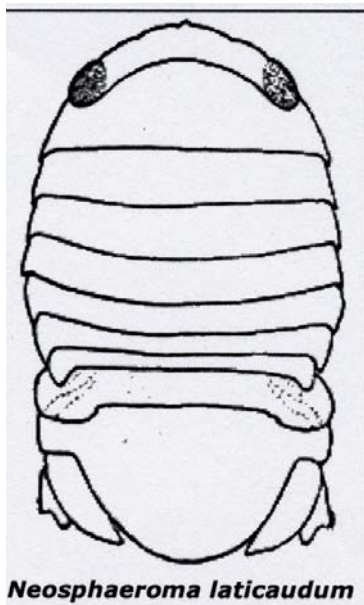


Figure 2. *Neosphaeroma laticaudum*. (from Hale, 1929: 274; Fig 272.) and a photograph of the specimen obtained from HMAS Dechaineux.

5.1.3 *Paracerceis sculpta*

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Paracerceis sculpta (Holmes 1904)

Poore, 2002: 244; NIMPIS, 2006: 2

(www.marine.csiro.au/crimp/nimpis/spSummary.asp?txa=6281)

Type locality:

San Clemente Is., Ca., USA.

Distribution:

Hong Kong, California, Mexico, Hawaii, Brazil.

Introduced to Australia (from USA probably). In Australia, 200 m bathymetric, (Bass Strait, Central East Coast, Lower East Coast, NE Coast, Southern Gulfs Coast), NSW, QLD, SA, VIC, and WA;

Collection details:

HMAS Anzac, Western Australia, 21/5/03, sample AA (stern)

HMAS Manoora, Sydney, 10/11/03, sample AJ (Keel strake, DDSS)

HMAS Westralia, Western Australia, 1/8/03, sample AD (Bow paint damage), and J (hull taper aft)

Associated species:

HMAS Anzac: Barnacles: *Amphibalanus amphitrite*, and *Balanus trigonus*

HMAS Manoora: None

HMAS Westralia: Tubeworms: *Hydroides elegans*; Barnacles: *Amphibalanus amphitrite*;

Bivalve molluscs: *Mytilus galloprovincialis planulatus*; Ascidians: *Ciona intestinalis*, and *Diplosoma listerianum*.

Diagnosis:

The length of adult males is variable with a relatively slender body, about 2.1 times as long as wide, anterior margin of head with median projection (Figure 3). The dorsal surfaces of the head and pereon are almost smooth, each bearing 3 or 5 bundles of setae posteriorly. The pleon and anterior part of the pleotelson are granulose. The pleon has a low, bifid, central tubercle and one simple tubercle on each side. The pleotelson bears three pronounced longitudinal ridges, the central being dorsally concave. Posterior to the main dome, the pleotelson bears an intricate, symmetrical arrangement of short setae surrounding a prominent median conical tubercle. The lateral margins of the pleotelson are straight, and the apex is extended into a broad deep median notch. The notch consists of a central anterior tooth and a large curved anterolateral tooth at each side. This deep notch is indicative of the male type of *P. sculpta*. The posterior margin of the pleotelson, between the notch and the lateral margins is slightly indented. The colouration is mainly dark brown, and rarely pink or light brown (Harrison and Holdich, 1982a).

The length of non-ovigerous adult females is also variable, but they are smaller than the males. The body is ovate, about 1.9 times as long as wide. The anterior margin of the head and pereon is smooth, each bearing a few posterior setae. The pleon is also smooth, and the posterior margin has 3 bundles of setae. The middle part of the pleotelson has 3 setose tubercles. The apex of the pleotelson is shallowly concave. This condition is vastly different to the male, and is indicative of the female type of *P. sculpta*. The endopod and exopod of the uropod are flattened with marginal setae. The exopod is lanceolate and the

apex is pointed. The colouration consists of dark red with white dorsal band, dark brown or light brown (Ariyama & Otani, 2004).

Comments:

Paracerceis sculpta is native to the Northeast Pacific, originally extending from southern California (Miller, 1968) to Mexico (Menzies, 1962). However, its distribution now includes Brazil (Pires, 1981), Hawaii (Miller, 1968), the Atlantic Coast of Europe (Rodriguez, 1992), the Mediterranean (Rezig, 1978), Hong Kong (Bruce, 1990), and Australia (Harrison and Holdich, 1982a). The wide distribution of this species has been attributed to its intimate association with epibenthic fouling organisms, such as algae and sponges, and high potential for infestation of ballast waters which both facilitate ship borne translocation between ports (Poore & Storey, 1999).

The first collection of *P. sculpta* in Australian waters was from a pontoon in the Port of Townsville in 1975 (Harrison and Holdich, 1982a). Subsequently, *P. sculpta* was found in Western Australia, in Bunbury, Mandurah (Peel Inlet), the Swan River and Port Denison (Hass & Knott, 2000). This recent discovery of *P. sculpta* in these ports, which are known to provide the first-port-of-call for international ships, has strengthened the theory that trans-Pacific shipping is the vector for the introduction of species such as *P. sculpta* (Hewitt & Campbell, 2001).

Most of the specimens of *P. sculpta* identified in this study were from ships at Garden Island in Western Australia, with one from Sydney. This is not unexpected, due to its known presence in South Western Australian (see above). The navy ships in this survey from Western Australia were berthed in Careening Bay in the southern part of Cockburn Sound, which is within the reported geographic range for *P. sculpta*. Specimens from *HMAS Anzac* included both male and female species, which indicates an established breeding colony with the potential for range expansion.

The specimens found on *HMAS Manoora*, berthed in Sydney, also indicate the presence of colonies established in and around the areas of Sydney. Although not previously reported from Sydney, *P. sculpta* has been collected from Eden, Botany Bay, and Wollongong Harbour, from as early as 1996 (Pires, 1981). The presence of *P. sculpta* in Sydney is therefore not unexpected.

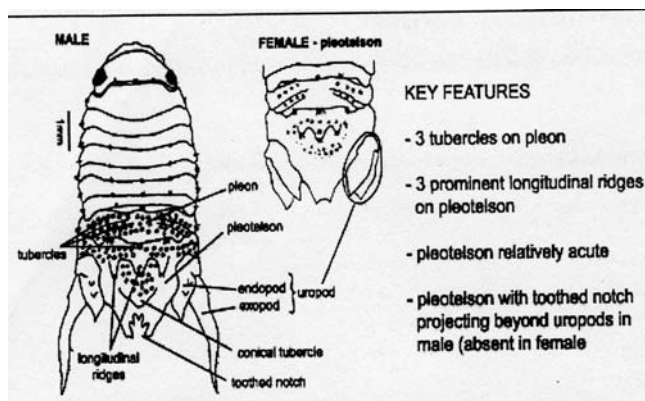


Figure 3. *Paracerceis sculpta*. (from NIMPIS, 2006: 2) and a photograph of the specimen (male) obtained from HMAS Anzac.

5.1.4 *Sphaeroma walkeri*

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Sphaeroma walkeri Stebbing 1905

Poore, 2002: 249; NIMPIS, 2006:1

(www.marine.csiro.au/crimp/nimpis/spSummary.asp?txa=8598)

Type Locality:

Sri Lanka

Distribution:

Australia, 200 m, bathymetric (Central East Coast, NE Coast) of QLD, India, Sri Lanka, Indian Ocean coast of Africa, Mediterranean Sea, Caribbean Sea, Hawaii;

Collection Details:

HMAS Adelaide, Western Australia, 10/7/03, sample G (Rudder strop holes) and K (Transom)

HMAS Hawkesbury, Sydney, 24/11/03, sample N (DDSS)

HMAS Ipswich, Cairns, 9/5/04, sample IR (DDSS)

HMAS Melville, Cairns, 9/5/04, sample MK (Bilge keel upper and lower), MO (Rudder stock and rudder), MU (APU & housing)

HMAS Rankin, Western Australia, 27/10/03, sample R (Recessed circular covers; fwd of EPU)

HMAS Shepparton, Cairns, 8/5/04, Sample SX (Anodes)

HMAS Sydney, Western Australia, 17/8/03, sample D (Rudder)

Associated Species:

HMAS Adelaide: Algae: *Ulva* (*Enteromorpha*) sp.; Barnacles: *Balanus trigonus*
Amphibalanus amphitrite, *Megabalanus* spp.; Tubeworms: *Hydroides* spp.
 HMAS Hawkesbury; HMAS Ipswich; HMAS Melville; HMAS Shepparton;
 HMAS Sydney: Barnacles: *Amphibalanus amphitrite*

Diagnosis:

The adult male has an antenna with 5-segmented peduncle and flagellum of 14 to 15 articles. Each article of the flagellum bears a fringe of smooth setae up to two or three times the length of the article. The interior endite of maxilliped has a fringe of 11-13 robust, plumose setae with swollen base on internal border. The semicircular distal margin of the endite has a bare setae. The robust polp segments II-IV lack lobes, with straight interior margins bearing dense fringes of long, fine-plumose setae. The ratio of width of the third segment to that of protruding internal margin is 6:1. The external distal corner of the third and fourth segment bear 4-7 and 7-10 long bare setae, respectively.

The propodus of pereopod 1 has a stout comb-like infero-distal spine and one serrated rostro-distal spine. The near rostro-distal spine transverses a row of 10 long plumose setae which are inserted. The merus and ischium bear tergally, 30-40 and 50-60 long, plumose setae, respectively. These setae, ending in a short spine (about 1/10th of total length of seta), are densely and regularly plumose with the length of setules best developed caudally. The dorsal surface of pleotelson bears four long, longitudinal rows of prominent tubercles, two on either side, parallel to midline. There is an anterior insertion of uropod pleotelson with short row of tubercles. The dorsal surface of body has rows of prominent tubercles along posterior margins of pereonites. In the lateral view, the pleotelson is subapically concave and the posterior margin of apex straight and crenated. In older specimen, the distal half of lateral margin of pleotelson is raised, giving a spoon like appearance. The uropodal rami are robust, usually reaching beyond the posterior margin of the pleotelson. The external margin of exopod has 5-7 pronounced teeth, mostly situated in caudal region.

The adult female is the same as the male, except that the flagellum bears a fringe of smooth setae reaching only as far as the next segment, and both uropodal rami reach only to the posterior margin of pleotelson.

Comments:

Sphaeroma walkeri is considered to be indigenous to the northern Indian Ocean (Carlton & Iverson, 1981). Material collected in 1902 by Thomas Stebbing, and subsequent records from India, showed it to be widely distributed along both the east and west coasts, in the Arabian Sea as far north as Bombay, and in the Bay of Bengal north of the Orissa region (Miller, 1968). *S. walkeri* is reported to occur in crevices under the leafy growths of the bryozoan *Watersipora arcuata* Banta and in the empty shells of the barnacle *Balanus amphitrite amphitrite* Darwin (= *Amphibalanus amphitrite*) (Holdich, 1970).

S. walkeri is a warm water species with its northern and southern limits corresponding to marine winter isotherms of 15-20° Celsius (Carlton & Iverson, 1981). It is a non-boring, fully marine, shallow water (less than 5 m), thigmotactic isopod, that inhabits crevices, and is commonly found in fouling. Its distribution pattern is a good example of a harbour-dwelling synanthropic marine invertebrate.

The dispersal of *S. walkeri* can be directly linked to shipping. The opening of the Suez Canal in 1869 facilitated dispersal through to the Mediterranean seaports, with records from Port Said (before 1924) and Alexandria (before 1933) in Egypt and to Israel (before 1971) (Carlton & Iverson, 1981). The appearance of *S. walkeri* in the seaport city of Durban, South Africa is thought to have occurred before 1915, with positive identification of the species found in fouling on pilings in 1917 (Baker, 1920).

The first record of *S. walkeri* in Australia was from Port Jackson in 1927 (Baker, 1920). By around 1930, *S. walkeri* was found to have spread through many bays in Sydney Harbour, including Darling Harbour, Blackwattle Bay, Walsh Bay, Rozelle Bay, White Bay, and Mort Bay (Carlton & Iverson, 1981). In 1932 the species is listed as being “most conspicuous” in Port Jackson, and most abundant on timber in quiet waters of high salinity (Iredale et al., 1932). However, *S. walkeri* is not considered to be a wood boring species, but dwells in tunnels created by other species (Palekar & Bal, 1957). *S. walkeri* was first recorded in South Australia in 1928 from surface fouling on test panels (Baker, 1920).

Moritz (1945) reported *S. walkeri* from San Juan, Puerto Rico, in 1942, and from Brazil, from Fortalenza in the north to Matinhos in the south and including the major port of Rio de Janeiro, in 1953. Its spread to Hawaii around 1943 was attributed to ship movements during WWII, from the Indian Ocean or Australia, and from Hawaii it spread to California sometime before 1973 (Highsmith, 1985).

In 1967 *S. walkeri* was collected in Townsville, Queensland, and the source was considered to be shipping from the Indian Ocean (Carlton & Iverson, 1981). However, it is perhaps more likely to be a northern translocation on shipping from Sydney. In 2000, *S. walkeri* was found in the Port of Lucinda, a major port for shipping sugar located 100 km north of Townsville (Ports Corp. of Queensland, 1999) and has now been found in Cairns. Presence in other subtropical and tropical harbours has been attributed to shipping, rather than natural range expansion (Rostramel, 1972), and the northward movement of *S. walkeri* in eastern Australia is also likely to be “shipping driven”. The distribution of the species in Australia reflects its cosmopolitan distribution, and its tolerance of a wide variety of physiologically challenging environments within its cold thermal limitation (Hass & Knott, 1998). Both Sydney and Garden Island in WA have water temperatures above the cold thermal limitation of *S. walkeri* enabling colonisation of these locations.

S. walkeri was the most abundant species found in this survey. It has previously been reported to be found with one or both of the species *Dynamenella dianae* and *P. sculpta* (Carlton & Iverson, 1981) and the latter species was the second most common species we found. *S. walkeri* was collected from six ships, with home ports in Western Australia, New South Wales and North Queensland. *S. walkeri* was found on two ships berthed at Garden Island, Western Australia, and these appear to be the first records of the species in this

state. Two other *Sphaeroma* species, *S. quoyanum* and *S. serratum*, have been reported from the nearby Swan River (Hass & Knott, 1998), but with no mention of *S. walkeri* in the Swan River/Fremantle area. The number of specimens found on the navy ships suggests the presence of established populations of *S. walkeri* in Cockburn Sound.

S. walkeri was also identified on *HMAS Hawkesbury*, a vessel based in Sydney Harbour. This is no surprise given the long record of occurrence of *S. walkeri* in Sydney Harbour.

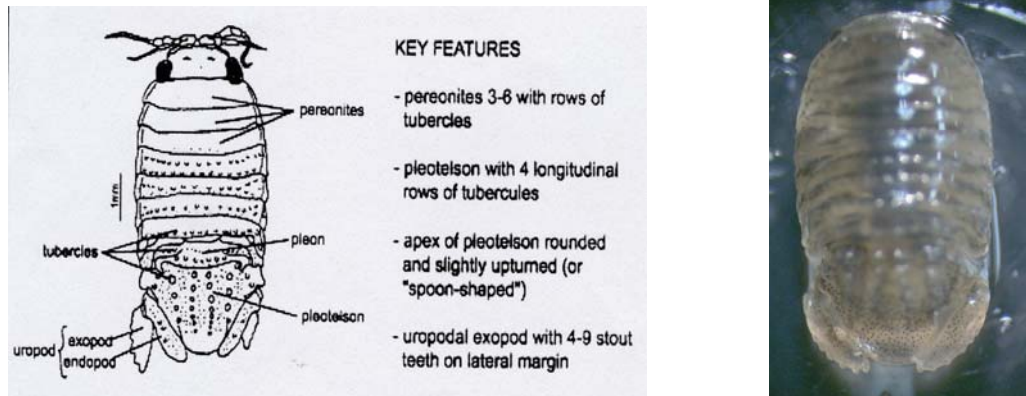


Figure 4. *Sphaeroma walkeri*. (from NIMPIS, 2006: 1;) and a photograph of the specimen obtained from HMAS Adelaide

5.1.5 *Cymodocella* sp.

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Cymodocella sp.

Pfeffer 1887; Poore, 2002

Distribution:

Exclusively southern hemisphere distribution, with the majority of species being recorded from southern Africa, and known species from southern Australian waters (Harrison & Holdich, 1982).

Collection Details:

HMAS Sydney, Western Australia, 17/8/03, sample K (Propeller)

Associated Species:

HMAS Sydney: Algae: *Ulva* (*Enteromopha*) sp; Barnacles: *Amphibalanus amphitrite*

Diagnosis:

An eubranchiate Sphaeromatidae with an antennular peduncle article 1, which is not extended anteriorly as a plate. Both sexes have a pereon and pleon which lack dorsal processes. Both sexes have rami of uropod lamella, and the endopod is greater than half the length of the exopod. The apex of the pleotelson has lateral margins that curve ventrally and meet at the midline producing a cylindrical, posteriorly directed aperture. All the pereopods have simple accessory unguis, and are not markedly bifid. The exopod of pleopod 3 lacks articulation and sexual dimorphism is not pronounced. In *Cymodocella*, the length of the endopod in relation to the exopod ranges from 1.43 to 1.69 for Australian species (excluding *C. ankylosauria*) and 1.08 to 1.17 for the South African species (excluding *C. sublevis* 0.83). There is obvious sexual dimorphism with the male being more ornate than the female.

In the adult male, the penes are short, stout and separate to the base. The appendix masculina arises from the internoproximal angle of the endopod of pleopod 2 and extends beyond the apex of the endopod. The exopod of the uropod is usually relatively longer than that of the female.

In the ovigerous female, the mouthparts are not metamorphosed, and the exopod of the uropod is usually shorter than that of the male. The brood pouch is formed posteriorly as a pocket, opening anteriorly at the level of pereopod 4; and anteriorly as three pairs of large oostegites arising from pereopods 2 to 4 and overlapping well in the midline. The brood are not incubated in the pouch, but in the invaginations of the ventral body wall.

Comments:

Species of the genus *Cymodocella* occur mainly in the Antarctic and southern temperate regions. Only the South American *C. gurarapariensis* and *C. faveolata* are known from the tropics. This group is almost exclusively found in the southern hemisphere, with most genera and species being recorded from Australia, New Zealand and South Africa (Bruce, 1993).

The three species of *Cymodocella* found in Australia are *C. ambonata*, from the lower east coast of NSW, *C. ankylosauria* from the Great Australian Bight and southern gulf coasts in SA., and *C. glabella* from Lord Howe Island. The *Cymodocella* species found in this study was collected from *HMAS Sydney* when berthed at Garden Island, WA, and did not resemble any of the three species known from Australia. The travel log for this vessel indicates that it travelled from Falconer in the Middle-East, but no information is available on any *Cymodocella* sp. from the middle-eastern ports. Conversely, the species may have been resident in Cockburn Sound, previously introduced by other vessels arriving in the port, and subsequently colonised *HMAS Sydney*, or could possibly be an undescribed species of *Cymodocella*.



Figure 5. A photograph of *Cymodocella* sp. collected from HMAS Sydney.

5.1.6 *Ischyromene* sp.

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Ischyromene sp.

Racovitza 1908; Poore, 2002

Distribution:

Cosmopolitan.

Collection Details:

HMAS Warramunga, Western Australia, 6/10/03, sample WRM009 (Transom)

Associated Species:

HMAS Warramunga: Algae: *Ulva* (*Enteromorpha*) sp.; Barnacles: *Amphibalanus amphitrite*

Diagnosis:

An eubranchiate Sphaeromatidae with an antennular peduncle article 1, which is not extended anteriorly as a plate. Both sexes have a pereon and pleon which lack dorsal processes. The pleon has posterior margin with two sutures on each side. Both sexes have both rami of uropod lamella, and the endopod is greater than half the length of the exopod. The apex of the pleotelson, has either a simple, ventral groove or an enclosed dorsally directed foramen. The pereopods are stout, and the accessory unguis is often

markedly bifid. The endopod of pleopod 1 is triangular with an internal half indurate. The exopod of pleopod 3 is without articulation. Sexual dimorphism is not pronounced.

The species of this genus can show a number of variable characteristics, of which the epistome variation between the species is a useful distinguishing characteristic. Some species are more or less flattened with laterally extended coxal plates. The pleotelsonic apex may have a simple groove or an enclosed foramen, and the pereopodal accessory unguis may be bifid or simple. The uropodal rami can be apically rounded (eg. *I. lacezi*) or they may have sinuous margins with the exopodal apex acute (eg. *I. australis*).

In adult males, pereonite 7 is often longer than that of females, with the posterior margin being markedly bilobed. The penes are short, and are separate to the base with rounded apices. The appendix masculina is narrow, and arises from the internoproximal angle of the endopod of pleopod 2 and extends to, or beyond, the apex of the endopod.

The mouthparts of the ovigerous female are not metamorphosed, and the brood pouch is formed posteriorly as a pocket, opening anteriorly at the level of pereopod 4, and forms three pairs of anterior large oostegites, which arise from pereopods 2 to 4, and overlap in the midline. The brood is not incubated in the brood pouch, but in the invaginations of the ventral body wall (Harrison & Holdich, 1982).

Comments:

This genus is found predominately in temperate regions, centred in the southern hemisphere with the western Mediterranean the northern distributional limit of this genus (Harrison and Holdich, 1982). Three species of *Ischyromene* are known from Australia: *I. lacezi* has an extralimital distribution in the Southern Hemisphere; *I. polyta* is found along the central east coast of Queensland, and *I. rubida* along the lower east coast of New South Wales (Poore, 2002). The specimen recorded from *HMAS Warramunga* was collected while the ship was at Dunedin in New Zealand, but may have been translocated on the ship's hull from Australia. However, the isopod found did not match any of the three Australian species. Neither did the isopod match any of the species native to New Zealand: *I. condita*, *I. cordiforaminalis*, *I. hirsute*, *I. huttoni*, *I. insulsa*, and *I. mortensi*. The origin and distribution status of this specimen therefore remains unclear.



Figure 6. A photograph of *Ischyromene* sp. collected from HMAS Warramunga

5.1.7 *Pseudosphaeroma* sp.

Order Isopoda: Suborder Flabellifera: Family Sphaeromatidae

Pseudosphaeroma sp.

Chilton 1909; Poore, 2002: 247

Distribution:

Bass Strait, Victoria; New Zealand, Snares Is, Campbell Is, Chile, Tristan da Cunha.

Collection Details:

HMAS Darwin, Western Australia, 1/12/03, Sample F (Port P47-P37)

HMAS Canberra, Western Australia, 27/10/03, Sample Ran-F (masker belt guard).

Associated Species:

HMAS Darwin: No information

Diagnosis:

Eubranchiate. The antennular peduncle article 1 is not extended anteriorly as a plate. Both sexes have a pereon and pleon lacking dorsal processes. The pleonal posterior margin bears two curved parallel sutures at each side. Both sexes have both uropodal rami lamellar. The entire pleotelsonic apex is upturned. The maxillipedal palp articles, 2 to 4 bear low setigerous lobes. Pleopod 5 exopod has an apical toothed boss, extended sub-

apical boss, and medial boss. The branchial folds on the rami of pleopod 4 and 5 are few in number, and do not cover the entire ramal surface. Sexual dimorphism is not pronounced.

In the adult male the penes are separate, broad, with semi-circular tips. The appendix masculina arises from the medio-proximal angle of the endopod of pleopod 2 and extends beyond the ramal apex, dilating distally. The dorsal tuberculation in the male is more pronounced than in the female. The pereopods have inferior pads of fine setae (Harrison, 1984b).

In the ovigerous female the mouthparts are not metamorphosed. The brood pouch is formed from three pairs of oostegites arising from pereonites 2 to 4 and overlapping well in mid-line. The oostegites increase in size posteriorly. The brood is not housed in the marsupium thus formed, but in four pairs of internal pouches. The ventral pockets are absent. The pereopods lack inferior pads of setae.

Comments:

The one recorded Australian species of *Psuedosphaeroma* is *P. campbellensis*, which has been recorded from St Leonards and Swan Bay in southern Port Phillip Bay, Franklin River in Corner Inlet, Victoria, and from northern and southwestern Tasmania (Poore, 2007), as well New Zealand, the Snares Islands and the Campbell Islands. However, there has been doubt expressed by Neil Bruce as to whether the Australian species is *P. campbellense*, and assessment of material from New Zealand, South America and California may indicate the involvement of several species. The isopod was found on *HMAS Darwin*, berthed in Garden Island WA. Prior to the collection of the samples, the vessel had travelled to the Middle East, via the Seychelles, and Diego Garcia. On return to Australia, its first port of call was Townsville, followed by Gladstone, Brisbane, Adelaide and then finally Garden Island in WA. However, rather than coming from overseas, or another Australian port, it seems more likely that the isopod came from an established population in the WA port at Garden Island. *Pseudosphaeroma* specimens have also been collected on settlement ropes, used to monitor the settlement of mussels in this port (unpublished results), which provides evidence of a local colony. The specimen found on *HMAS Darwin* did not match *P. campbellensis*, so it is either an introduced species or one that has not yet been described.

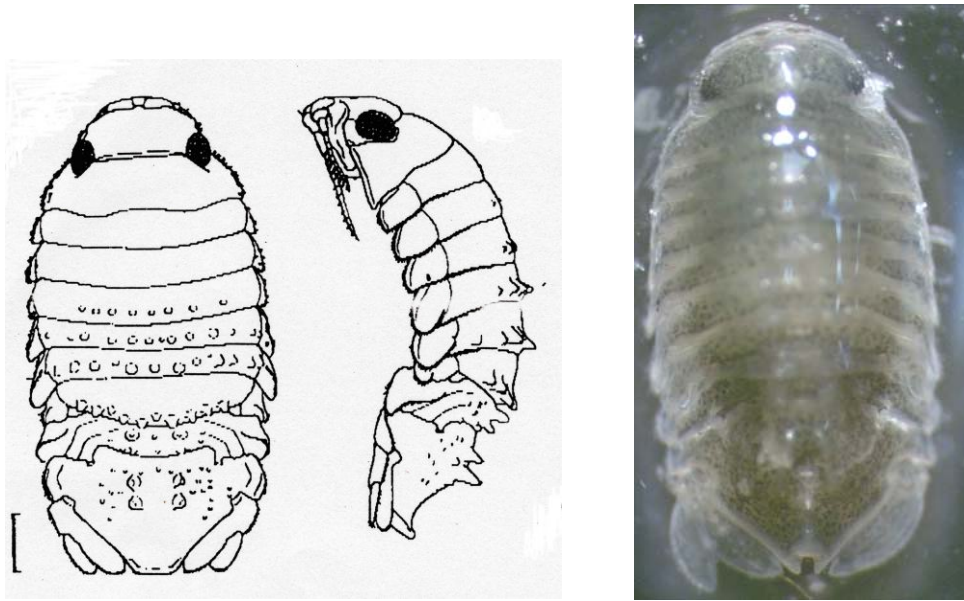


Figure 7. *Pseudosphaeroma campbellensis* and a photograph of *Pseudosphaeroma* sp. collected from HMAS Darwin. Note: tubercles on pleotelson are not visible in photograph but are visible under the microscope and are indicative of this genus.

Family Corallanidae

5.1.8 *Argathona* sp

Order Isopoda: Suborder Flabellifera: Family Corallanidae

Argathona sp.

Stebbing, 1905; Poore, 2002: 165-166

Distribution:

South and West Australia, QLD, Indo-West Pacific Oceans.

Collection Details:

HMAS Benalla, Cairns, 9/5/04, sample BE U, (DDSS)

Associated Species:

HMAS Benalla: No information

Diagnosis:

The genus has an antennule peduncle that is biarticulate, with the basal article not expanded. The frontal lamina is prominent and the clypeus has lateral margins that are backwardly produced, encompassing the labrum. The mandible has a narrow cutting

edge with a large triarticulate palp, and the molar process is present. The maxillule has an exopod terminating in an unguis-like point at the base of which lie one or more recurved hook-like processes. The endopod is a truncate lobe. The maxilla consists of a single simple lobe. The maxilliped has a 5-articulate palp, showing all degrees of fusion between articles 2 and 3. The pereopods 1-3, have dactyls that are sub-prehensile and without digitiform processes, and pereopods 4-7 are ambulatory. The pleopods are all similar; the endopod of pleopod 5 is non-setigerous (Poore, 2002).

In the adult male, the appendix masculina arises basally on the endopod of pleopod 2.

Comments:

The genus *Argathona* is distributed through the Indo-West Pacific Oceans, including Australia. There are six species of *Argathona* found in Australian waters, all from along the coast of Queensland (Poore, 2002). The occurrence of *Argathona* species in north-east Queensland and, their presence on a patrol boat operating out of Cairns and the north-eastern coastline, is not surprising.



Figure 8. A photograph of *Argathona* sp. collected from HMAS Benalla.

Family Cirolanidae

5.1.9 Cirolana sp.

Order Isopoda: Suborder Flabellifera: Family Cirolanidae

Cirolana sp.

Leach, 1818; Poore, 2002: 141-145

Distribution:

Australian Region; cosmopolitan

Collection Details:

HMAS Adelaide, WA, 10/7/03, Sample G (Rudder strop holes).

Associated Species

HMAS Adelaide: Barnacles: *Balanus trigonus*, *Amphibalanus amphitrite*, *Megabalanus* spp.;
Tubeworms: *Hydroides* spp.

Diagnosis:

Pleonite 1 is often concealed by pereonite 7. The lateral margins of pleonite 5 are covered by those of pleonite 4. The pleotelson has a posterior margin with setae and spines. The frontal lamina is flat, and about twice as long as it is wide, and the clypeus is sessile. The antennal peduncal articles are longest at 4-5. The pereopods 1-3 have anterodistal margins of the ischium and the merus is not produced. The pleopod peduncle is without lateral lobes, and only the endopod of pleopod 5 is without setae.

All species of Australian *Cirolana* have nodular sculpting in the form of tubercles, and have the uropod exopod lateral margin with discontinuous plumose setae (i.e. occurring in widely spaced groups) and fewer robust setae, or the rostrum meeting the frontal lamina.

In the adult male, the appendix masculina is inserted basally (Delaney, 1986).

Comments:

The genus *Cirolana* is very common throughout the Australian region. There are currently 29 species and one unnamed species of *Cirolana* Leach, 1818, known in Australian waters, ranging from the temperate waters of Tasmania to the tropical waters of the Great Barrier Reef. Cirolanid isopods are more diverse in tropical rather than temperate Australia (Bruce, 1986). At least seven species occur on the west coast of Australia (Keable, 1997). Given the wide distribution as well as the large number of species, the discovery of a *Cirolana* sp. on HMAS Adelaide in WA, is not considered unusual.



Figure 9. A photograph of *Cirolana* sp. collected from HMAS Adelaide. Note: identification of species was made under the microscope and not from this photograph

5.2 Caprellidea

Family Caprellidea, White, 1847 emend

Four caprellid species were collected and identified from the RAN ships surveyed (Table 3). The most abundant species was *C. equilibra*, with lesser numbers of *C. penantis* and *C. californica*. There were several specimens of *Paracaprella pusilla*, recorded in the samples examined from Cairns. All the specimens of *P. pusilla* were taken from local boats and consisted of 2 males and several females some ovigerous. It is likely that this is a local population, which has established itself in the Port of Cairns. This survey has recorded *C. californica* in both Sydney Harbour and Cockburn Sound, only a year later to the first Australian record in Sydney Harbour by the Sydney Ports Corporation.

Table 3. Identification of species found on RAN vessels (no. of caprellids found).

HMA SHIPS (Class)	HOME PORT (Survey Location)	LOCATION OF SPECIMEN	DATE	SAMPLE ID.	Caprellid Genus Species
Anzac (FFH Frigate)	W.A.	Stern	21/5/03	Screw	<i>C. equilibra</i> , (4) <i>C. californica</i> (1)
Brunei (Landing Craft)	Cairns	Rudder post, guard and rudder	9/5/04	BR E	<i>P. pusilla</i> (1)
		Damaged paint		BR G	<i>C. equilibra</i> (1) <i>P. pusilla</i> f. (1)
		Skeg		BR O	<i>P. pusilla</i> (1)
Darwin (FFG Frigate)	W.A.	Port (P47-P37)	1/12/03	F	<i>C. penantis</i> (12).
			1/12/03	V	<i>C. equilibra</i> (8)
		Hydrodine	1/12/03	J	<i>C. equilibra</i> (1)
Dechaineux (Submarine)	W.A.		1/8/03	YY	<i>C. equilibra</i> (1), <i>P. pusilla</i> f. (1)
Hawkesbury (Mine-hunter Coastal)	Sydney	DDSS	24/11/03	N	<i>C. californica</i> (1)
		Waterline FWD	24/11/03	E	<i>C. penantis</i> (2)
Wewak (Landing Craft)	Cairns	Seawater intake	9/5/04	L	<i>P. pusilla</i> (1)
		Rudder post and guard	9/5/04	J	<i>P. pusilla</i> f. (1)
		Skeg	9/5/04	E	<i>P. pusilla</i> (1)
Manoora (Amphibious Support ship)	Sydney	Bilge keel-Top circular zinc anode	1/7/03	CM	<i>C. equilibra</i> (1)
Melville (Hydrographic ship)	Cairns	Seachests	9/5/04	MT	<i>C. equilibra</i> (2)
		Rudder stock and rudder	9/5/04	MO	<i>P. pusilla</i> (1)
		APU & housing	9/5/04	MU	<i>P. pusilla</i> f. (2)
		Hull, lwr midships & aft	9/5/04	ML	<i>P. pusilla</i> f. (1)
		screw	9/5/04	MM	<i>P. pusilla</i> f. (2)
Shepparton (Patrol Boat)	Cairns	Transom	8/5/04	SQ	<i>P. pusilla</i> f. (2)
Waller (Submarine)		Upper hull, midship	13/5/03	2	<i>C. penantis</i> (1)
Warramunga (FFH Frigate)	WA (Dunedin NZ)	Rudder strope holes	10/6//03	G	<i>C. equilibra</i> (8)
		Transom	10/07/03	L	<i>C. penantis</i> (3)
Whyalla (Patrol Boat)	Cairns	Screw	8/5/04	S	<i>P. pusilla</i> (1)
		DDSS	8/5/04	H	<i>P. pusilla</i> f. (1)
		Bow lower	8/5/04	K	<i>P. pusilla</i> f. (2)
Westralia (Under-way Replenishment tanker)	W.A.	Bow paint damage	1/8/03	AD	<i>C. equilibra</i> (38), <i>C. californica</i> (1)
		Hull taper aft	1/8/03	J	<i>C. equilibra</i> (16), <i>C. californica</i> (7)
		Screw Blades fwd	1/8/03	H	<i>C. equilibra</i> (25)
		ICCP strip (aft stb)	1/8/03	E	<i>C. equilibra</i> (1)
		Prop. Blade aft	1/8/03	M	<i>C. equilibra</i> (4)
		Rudder	1/8/03	N	<i>C. equilibra</i> (9)
		DDSS aft	1/8/03	22	<i>C. equilibra</i> (2)

APU-Auxiliary propulsion unit; DDSS-Dry dock support strip; f-female

5.2.1 *Caprella californica*

Order Amphipoda: Suborder Caprellidea: Family Caprellidae

***Caprella californica* Stimpson, 1856**

Arimoto, 1976: 143

Type locality:
California

Distribution:
Pacific North America: Canada to Mexico; Chile; Hong Kong; South Africa.

Collection Details:
Hobsons Bay, Williamstown, Vic., 10/4/06 and 15/5/06
HMAS Anzac, Western Australia, 21/5/03, Screw (Stern)
HMAS Hawkesbury, Sydney, 24/11/03, Sample N (DDSS)
HMAS Westralia, Western Australia, 1/8/03, Samples AD (Bow paint damage), and J (Hull taper aft)

Diagnosis:
The body length in the adult male is especially elongate; pereonite 1 the longest of all segments, 2 a little shorter than 1, 5 shorter than 2, 3 a little shorter than 5, 4 a little shorter than 3, 5 and 7 taken together a little shorter than 4; the head is armed with a strong forward curved horn dorsally, pereonite 1 is smooth, pereonite 2 is somewhat thickened toward rear part, and with a small ventral spine between insertions of 2nd gnathopods, pereonite 3 and 4 each have an antero-lateral spine and rearward-lateral spine, pereonite 5 has a dorsal process at rear part, pereonites 6 and 7 each have a pair of dorsal processes.

Antenna 1 is longer than the head plus pereonites 1 and 2, the flagellum is a little shorter than segment 2 of the peduncle, and is 20-segmented; antenna 2 is a little longer than segments 1 of peduncle of antenna 1 and flagellum have swimming setae.

Gnathopod 2 is attached to rear part of pereonite 2, its basal segment is a little shorter than pereonite 2, the propodus is longer than basal segment, and rather longer than four-times its width. It is narrow proximally and widens distally, the medial of the palmar has an associated accessory spine, distally with a triangular tooth. The poison tooth is situated near a triangular projection with narrow notch and feathery spines on all its surface.

The gills are elongate. The mouth is typical of this genus.

Pereopod 5 a little shorter than pereonite 5, its propodus has palmar spines placed a little lower down, and dorsal margin with a set of spines.

Pereonite 5 in the adult female is the longest of all segments, 2 a little shorter than 5, 3 a little shorter than 2, 4 a little shorter than 3, 6 and 7 taken together a little shorter than 4, 1

is about as long as head. The head has an acute dorsal tooth, pereonite 1 carries a dorsal tooth at the distal end, pereonite 2 has two dorsal tubercles, the larger one behind centre, and the smaller one at distal end, pereonites 3 and 4 each have a couple of dorsal teeth at about centre and at distal end, pereonite 5 has a dorsal tooth at about centre, pereonite 6 and 7 each have one dorsal tooth and a pair of dorsal processes.

The flagellum of antenna 1 is 20-segmented; antenna 2 a little shorter than peduncle of antenna 1.

Gnathopod 2 is attached to near front of pereonite 2, segment is 1 shorter than pereonite 2, the propodus is large, rather twice as long as its breadth. The palm has a proximal grasping spine, an accessory spine and a minute distal poison spine, and triangular tooth.

The gills are oval.

Comments:

C. californica is known from the Pacific coast of North America, Mexico, Chile, Japan, Hong Kong, and South Africa. It is considered to be native to North America and introduced elsewhere. The first record of the species in Australia was in the baseline marine pest survey of Sydney Harbour undertaken by the Sydney Ports Corporation in 2002 (Port Survey, 1999/00). This survey has recorded *C. californica* in Sydney Harbour, Hobsons Bay in Victoria (Montelli, 2006) and also in Cockburn Sound. This may be the result of a geographical expansion of the species along the southern coastline of Australia; however no northerly expansion into the Port of Cairns was recorded in this survey. Another explanation may be the result of isolated introductions from international ports to the ports in question, with hull fouling the most likely vector.

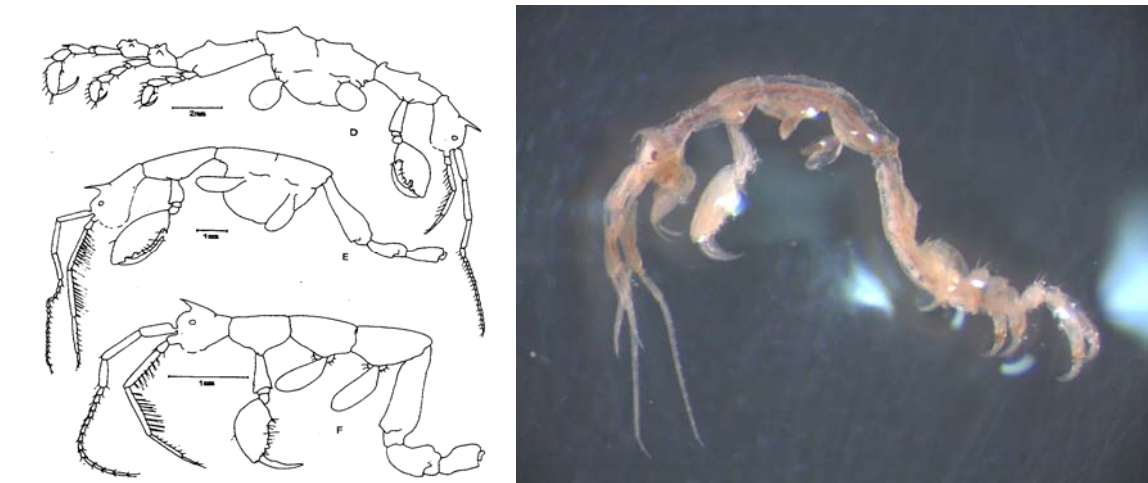


Diagram 1. *Caprella Californica* adult female: top and middle; juvenile female: bottom. (Arimoto, 1976) and a photograph of *C. californica* collected from HMAS Hawkesbury.



Diagram 2. A photograph of *Caprella Californica* adult male collected from HMAS Hawkesbury.

5.2.2 *Caprella equilibra*

Order Amphipoda: Suborder Caprellidea: Family Caprellidae

***Caprella equilibra* Say 1818**

Arimoto, 1976: 199

Caprella aequilibra, Bate, 1862

Caprella caudata, Thomson, 1879

Caprella Esmarkii, Boeck, 1861

Type locality:

South Carolina, USA.

Distribution:

Australia: 200 m bathymetric (Bass Strait, Lower E coast, Lower W coast, Tas. Coast); Europe: Sweden and Norway to the Mediterranean Sea including the British Isles; Mediterranean Sea; Black Sea; Azores; Africa: Tropical West to South Africa; East and west coast USA; Trinidad; Venezuela; Brazil; Argentina; Chile; Panama; Galapagos Islands; Mexico; British Columbia; Hawaii; Japan; Philippines; New Zealand; Hong Kong; Singapore; Malaysia.

Collection Details:

Hobsons Bay, Williamstown, Vic., 10/4/2006 and 15/5/2006

Careening Bay, Cockburn Sound, WA., May, 2004-June2006

HMAS Anzac, Western Australia, 21/5/03, Sample Screw (Stern)

HMAS Brunei, Cairns, 9/5/04, Sample BR G (Damaged paint)
HMAS Darwin, Western Australia, 1/12/03, Samples V and J (Hydrodine)
HMAS Dechaineux, Western Australia, 1/8/03, Sample YY
HMAS Manoora, Sydney, 1/7/03, Sample CM (Bilge keel-top circular zinc anode)
HMAS Melville, Cairns, 9/5/04, Sample MT (Seachests)
HMAS Warramunga, Western Australia, 10/6/03, Sample G (Rudder strope holes)
HMAS Westralia, Western Australia, 1/8/03, Samples AD (Bow paint damage), J (Hull taper aft), H (Screw blades forward), M (propeller blade aft), E (ICCP strip, aft stbd), N (Rudder) and 22 (DDSS aft).

Diagnosis:

The body colour is relatively clear with red-brown spots; the posterior margin of the dorsal surface of pereopods 2-4 with large red-brown spots increasing in size from pereopod 2-4; the spine between the attachment of gnathopod 2 is highly pigmented; antenna 1 is dark; gnathopod 2 is spotted with red-brown dactylus banded with red-brown; the gills are scattered red-brown spots. (McCain , 1970)

Male: Pereonite 2 is longer than any other, 1 is shorter than 2, pereonites 3, 4 and 5 are subequal and a little shorter than 1, 6 and 7, taken together they are a little shorter than 5; the head is smooth but angularly projecting in front, pereonite 1 is smooth and very long, pereonite 2 is furnished posteriorly with a straight triangular flat tooth in ventral medial line between gnathopods 2, pereonites 3 and 4 are smooth except for a ventro-lateral tooth on each side situated at fore end, pereonite 5 is constricted in front and with a ventro-lateral tooth on each side at the fore end.

Antenna 1 is about two-thirds of the body length, its segment 1 of peduncle is longer than its head, 2 more than twice the length of 1, 3 longer than half of 2. The flagellum is 13-segmented, and a little shorter than segment 3 of the peduncle and suddenly becomes narrow distally, antenna 2 is a little shorter than peduncle of antenna 1, with swimming setae.

The mandibles have large cutting teeth, the edges are divided into 5 strong plates. The lacinia mobilis is definitely divided like principal plate, with 2 or 3 setal rows, the molar tubercle is strong, with a powerful tooth on the front border giving the crown a very irregular outline; the inner lobe of maxilla 1 is underdeveloped, the outer lobe is smaller than the palp, bearing seven spines at distal margin, segment 1 of palp is short, segment 2 widens towards the obliquely convex dentate distal part, with many slender spines on apical surface and inner margin. The inner lobe of maxilla 2 is shorter and more oval than outer with many slender spines with a round apical margin and descending toward inner margin for some distance, the outer lobe is oblong, with many long spines on the apical margin; the inner lobe of maxilliped is small and scarcely reaching beyond the base of segment 1 of palp, widening distally, with 4 long narrow spines near distal part of apical margin, the outer lobe is as long as the inner, with several long narrow spines, segment 1 of the palp is stout, with spines on the inner margin and one below the center of the outer margin and is fringed with long spines, segment 3 a little shorter than 2, its inner margin is crowded with spines, especially on inner surface.

Gnathopod 2, originates from the posterior part of pereonite 2, the basal segment is quite short, the propodus is very large and oblong in form, tapering distally, the palm is sparingly setous, the palmar spine is located at the base and is provided with a grasping spine at the point, the poison tooth is situated near by a triangular tooth at the distal angle of palm, with a narrow notch in between.

The gills are oval to elliptical.

Pereopod 5 is a little longer than pereonite 5, pereopod 6 a little longer than 5, 7 a little longer than 6. The propodus of 5-7 is robust with 2 grasping spines proximally.

The abdomen is typical of genus.

Female: The body is very much smaller than the male; the female is very like the male, except for the development of the oostegite; pereonite 1 is about as long as the head, pereonite 2 is longer than any other segment, 3 a little shorter than 2, 4 a little shorter than 3, 5 a little shorter than 4, 6 and 7 taken together is a little shorter than 5.

Antenna 1 a little shorter than half of the body length, its flagellum is 16-segmented; gnathopod 2 is attached rather to the front part of pereonite 2, the propodus is large, a little shorter than pereonite 2 and twice as long as wide, and is located proximally with a projecting palmar angle bearing a spine. The small poison tooth is situated near by a triangular tooth at distal angle of palm. The gills are oval in form.

Comments:

C. equilibra was first described from eastern USA, and occurs on all continents and many islands. It ranges from intertidal down to 3000 m depth. The complex synonymy, morphological differences between populations and great depth range suggest that the species' distribution may be ancient and natural but this has never been tested.

It was first recorded in Port Jackson, NSW, Australia as *C. obesa* by Haswell (1884b), and in Victoria by Haswell (1884b). The latter is likely to have been from Port Phillip Bay (Poore & Storey, 1999). *C. equilibra* is widespread around the coast of Australia; the presence of the caprellid in all the major ports listed in the survey would indicate this. It was the most abundant species collected from the ships in WA, with 100 individuals or approximately 90% of the total caprellids collected, identified as *C. equilibra*. This caprellid was also collected from a ship that had been berthed in New Zealand, which in light of its distribution would be expected. Both Sydney Harbour and the Port of Cairns, had far lower numbers of caprellids, and the total number of *C. equilibra* consisted of not more than 1 or 2 individuals for each port.



Diagram 3. *C. equilibra*: A-adult male; B,C-young male; D-larva. (Arimoto, 1976) and a photograph of *C. equilibra* collected from HMAS Manoora.

5.2.3 *Caprella penantis*

Order Amphipoda: Suborder Caprellidea: Family Caprellidae
***Caprella penantis*, Leach 1814**

Arimoto, 1976: 216

Caorella penantis, Stebbing, 1910
Caprella novaezealandiae, Kirk (1878)
Caprella obesa, Beneden, van (1861)
Caprella cornalia, Nardo, (1869)
Caprella spinifrons Nicolet, (1849)
Caprella geometrica, Say, (1818)
Caprella acutifrons, Latrielle, 1816

Type locality:

Devonshire Coast, England.

Distribution:

Australia: 200 m bathymetric (Bass Strait, Lower E coast, S Gulfs coast); temperate (Pacific Ocean, Atlantic Ocean); Atlantic coast of France, Spain and Portugal; British Isles; Azores; Mediterranean Sea; Atlantic coast of North America from Nova Scotia to Georgia; Panama; French Guiana; Falkland Islands; Chile; South Africa; California; Hawaii; Japan; Hong Kong; New Zealand

Collection Details:

Hobsons Bay, Williamstown, Vic., 10/4/06 and 15/5/06

Careening Bay, Cockburn Sound, WA

HMAS *Darwin*, Western Australia, 1/12/03, Sample F (Port P47-P37)

HMAS *Hawkesbury*, Sydney, 24/11/03, Sample E (Waterline FWD)

HMAS *Waller*, Western Australia, 13/5/03, Sample 2 (upper hull, midships)

HMAS *Warramunga*, Dunedin New Zealand, 10/7/03, Sample L (Transom)

Diagnosis:

Male: The body is smooth except for head; pereonite 3 is longer than any other pereonite, 2 and 4 are subequal in length and a little shorter than 3, 5 and 6 are subequal in length and taken together a little longer than 4, 1 is a little shorter than 7; head with an anteriorly directed triangular projection; body is stout with some degree of pleural development observed on pereonites 3 and 4. It appears that the larger the animal grows, the more robust the body and the more well-developed the pleural plate to ventral-lateral side of pereonites 3 and 4.

Antenna 1 is a little shorter than half of the body length, its flagellum is a little shorter than the peduncle and is 14-segmented; antenna 2 is a little longer than the peduncle of antenna 1, and with setae.

Gnathopod 2 is attached rather to the front part of pereonite 2, basal segment is short, propodus is a little longer than pereonite 2, and about twice as long as its greatest breadth, with projections, but without palmar spine, with a distally oblong projection at distal angle of palm.

The gills are circular and large.

Pereopod 5 is a little longer than pereonite 5, pereopod 6 is a little longer than 5, and 7 is a little longer than 6, whose segments are wide, and the propodus has a pair of grasping spines.

The abdomen is typical of the genus.

The body is stout, pereonite 1 is shorter than any other pereonite, segments 1 and 2 of peduncle of antenna 1 are stout; the palm of propodus of gnathopod 2 has many spines.

Female: The body is smooth except for the head; pereonite 3 is longer than any other pereonite, 2 and 4 are subequal in length and a little shorter than 3, 5 a little shorter than 4, 6 and 7 taken together are a little longer than 5, 1 is the shortest of all pereonites; gnathopod 2 is attached to fore end of pereonite 2, propodus a little shorter than twice its greatest breadth, palmar margin is slightly convex, the palmar spine is proximal setose and with a small poison tooth and small distal projection. (Arimoto, 1976).

Comments:

C. penantis is widespread and morphologically variable leading to the proposal of numerous varieties (McCain 1965). Mayer (1903) first recorded the species from Australia

as *C. acutifrons*, on the basis of a specimen from Port Jackson (Stebbing 1910). A subsequent record is from South Australia (Hale 1929). The single specimen from Port Phillip Bay reported by Poore et al. (1994) cannot now be found or therefore confirmed. The only specimens from the Museum of Victoria were collected in Western Port in the 1960s (Poore and Storey, 1999).

C. penantis has been shown to prefer strong currents and clean water, with low levels of suspended solids and organic matter (Garcia, 2002). The species has been recorded from a coconut washed ashore on the Kermadec Islands, north of New Zealand, an observation supporting natural dispersal, but ship fouling is also a highly probable vector.

In this study we obtained specimens of *C. penantis* from; Williamstown, Victoria; Cockburn Sound, WA; and Sydney Harbour. Unlike *C. equilibra* and *P. pusilla*, no traces of *C. penantis* were found in the samples taken from ships berthed in Cairns. *C. penantis* is both a temperate and tropical amphipod however, unlike the other caprellids in this survey it prefers exposed areas (Bynum, 1979). Its absence from the Port of Cairns may be related to decreased wave exposure present in Cairns compared with the other sites at which *C. penantis* was found. It may also be a result of incomplete sampling, and further sampling may reveal the presence of *C. penantis*.

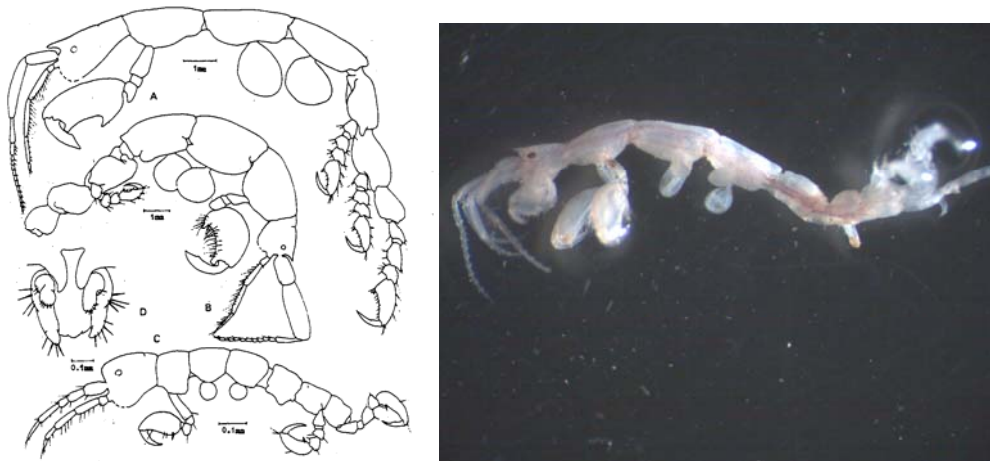


Diagram 4. *C. penantis*. A,B-adult male; C-larvae; D-abdomen. (Arimoto) and a photograph of *C. penantis* collected from HMAS Hawkesbury.

5.2.4 *Paracaprella pusilla*

Order Amphipoda: Suborder Caprellidea: Family Caprellidae: Subfamily Caprellinae

***Paracaprella pusilla* Mayer 1890**

Diaz (2005): 22

Type locality;

Rio de Janeiro, Brazil (McCain, 1968).

Distribution:

Brazil, Venezuela, Indian, Pacific and Atlantic Oceans, Suez Canal, tropical west Africa, South Africa, Tanzania, Hawaii, China, Gulf of Mexico, Cuba, Venezuela, Western North Atlantic.

Collection Details:

HMAS Brunei, Cairns, 9/5/04, Samples BR E (Rudder post guard and rudder) and BR O (Skeg)

HMAS Dechaineux, Western Australia, 1/8/03, Sample YY

HMAS Wewak, Cairns, 9/5/04, Sample L (Seawater intake)

HMAS Melville, Cairns, 9/5/04, Samples MO (Rudder stock and rudder), MU (APU & housing) and SQ (Transom)

HMAS Wewak, Cairns, 9/5/04, Sample E (Skeg)

HMAS Whyalla, Cairns, 8/5/04, Sample H (DDSS), Sample K and Sample S (Screw)

Diagnosis:

Males can be identified by the large, sharp-pointed projection on the anteroventral margin of pereonite 2, the proximal knob on the basis of gnathopod 2, and the presence of setae on the dactylus of gnathopod 2. The males also bear a small anterodorsal tubercle on pereonite 2 (Diaz. et.al., 2005).

P. pusilla has been collected from mangrove roots, seagrasses, hydroids and ascidians (McCain, 1968).

Comments:

P. pusilla has been found in Brazil and in particular, areas such as tropical west Africa, and Hawaii, which reflect similar conditions found in Far North Queensland, and not surprisingly, *P. pusilla* has established itself in the Port of Cairns, with several specimens in these waters, including 2 males and several females found on patrol boats local to the area. *P. pusilla* has not been reported in Australian waters previously, and the most likely means of introduction into Australian waters is translocation via shipping. Its geographical distribution indicates a preference for tropical waters, which may limit it to Far North Queensland. One specimen was found in Cockburn Sound in WA, whether this is an isolated incident, which may be the case with the presence of only one specimen, or alternatively an indication of another site of translocation from an international port, will require further investigation. The Port of Cairns is 3rd after Brisbane and Hay Point in the frequency of international ships that visit that port, and it is highly likely that ships arriving from ports such as China or Hawaii are a possible means of the introduction of *P. pusilla* into Australian waters.

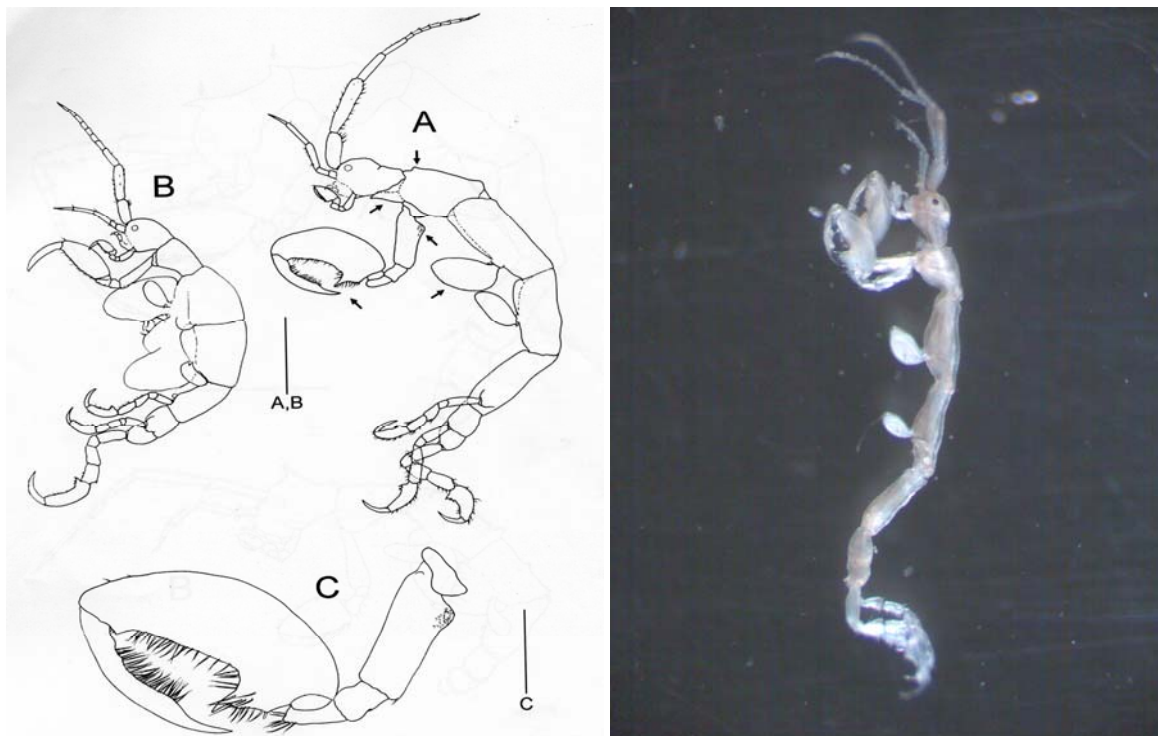


Diagram 5. *P. pusilla*. A, Male; B, Female; both lateral views. C, Male gnathopod 2. (Diaz) and a photograph of *P. pusilla* collected from HMAS Wewak.

6. Discussion

6.1 Isopoda

Table 4 is a summary of the results, and lists the species found against geographic location, and whether they have been previously recorded in that region. "Australian species", indicates that species of this genus are known from Australian waters, but the reference material in hand is inadequate to enable species identification, to either confirm or eliminate the species as native. "Introduced or undescribed" species indicates that species of that genus are known in Australian waters, but the specimens in hand do not match the known literature.

Table 4. Summary of species found on HMAS Navy Ships at the inspection location.

Port	Genus	Species	Previously Recorded in port	Date
Western Australia	<i>Cirolana</i>	<i>sp</i>	Undetermined (Australian species)	July, 2003
	<i>Cymodocella</i>	<i>sp</i>	Undetermined (Introduced or undescribed)	Aug, 2003
	<i>Neosphaeroma</i>	<i>laticaudum</i>	No	Aug, 2003
	<i>Paracerceis</i>	<i>sculpta</i>	Yes	May, 2003
	<i>Pseudosphaeroma</i>	<i>sp</i>	No	Dec, 2003
	<i>Sphaeroma</i>	<i>walkeri</i>	No	Aug, 2003 July, 2003
Sydney	<i>Cymodoce</i>	<i>gaimardii</i>	Yes	July, 2003
	<i>Paracerceis</i>	<i>sculpta</i>	Yes	Nov, 2003
	<i>Sphaeroma</i>	<i>walkeri</i>	Yes	Nov, 2003
Cairns	<i>Argathona</i>	<i>sp</i>	Undetermined (Australian species)	May, 2004
	<i>Sphaeroma</i>	<i>walkeri</i>	No	May, 2004
Dunedin, NZ	<i>Ischyromene</i>	<i>sp</i>	Undetermined (Introduced or undescribed)	Oct, 2003

In a port or harbour, the direct transfer of isopod species from one vessel to another, though possible, is considered far less likely to occur, than transfer to a ship from the local environs, such as wharf structures, or other habitats within a harbour. In contrast to the extensive fouling growth on harbour infrastructure, niches on ship hulls are relatively small, and due to the use of antifouling paints over most of the underwater hull, have far less fouling present. When an isopod is translocated to a new port, it is expected that the species would need to first colonise that port, before being translocated on ships sailing from that port. However, unlike fouling species, which need to colonise ships through spore or larval settlement, the mobility of isopods would enable mature individuals to seek and colonise suitable niches. Most of the isopods collected were associated with established fouling communities, most commonly acorn barnacle communities.

S. walkeri and *P. sculpta* are the most common species in this survey, in that order. The introduction of *S. walkeri* into Australian waters in southeastern Australia in the late 1920s was the likely springboard that was responsible for the subsequent colonisation of other Australian ports. The findings on *HMAS Hawkesbury* berthed in Sydney Harbour, confirmed the continued presence of *S. walkeri* in the Port of Sydney, as previously reported (Ireland et al, 1932; Carlton & Iverson, 1981).

S. walkeri was first recorded on the Queensland coast, from Townsville in 1967, followed by Port Lucinda, 100 km north of Townsville, in 1999. The northward expansion of *S. walkeri* was most likely facilitated by shipping, as both these ports are significant commercial ports. Our survey found *S. walkeri* on three ships based in Cairns. The presence on multiple vessels indicates an established population in the Port of Cairns.

The discovery of *S. walkeri* on ships in WA is the first report of species in southern WA, though two other *Sphaeroma* spp., *S. quoyanum* and *S. serratum* have been found in the Swan River (Hass & Knott, 2000). The presence of several individuals and in multiple sites on the ship where *S. walkeri* was found, suggest that a population is present in Cockburn Sound. However it may represent a relatively recent colonisation.

P. sculpta is an introduced species that was first collected from a pontoon in the Townsville port in 1975. The reports of *P. sculpta* in WA and Sydney are from the last ten years, with *P. sculpta* first recorded in Eden, Botany Bay and Wollongong Harbour in 1996 (Hewitt, 2001). *P. sculpta* is also known from Port Phillip Bay (Pollard and Hutchings, 1990). The first reports of *P. sculpta* in WA came from the ports of Bunbury, Mandurah, Port Denison and the Fremantle/Swan Rivers, in 2000 (Hass & Knott, 2000). The introduction of *P. sculpta* into these areas would, most likely, have also been as a result of shipping translocations. The presence of established populations of *P. sculpta* in Sydney and WA harbours would explain the presence of *P. sculpta* on ships based in these harbours.

C. gaimardii appears to be a Southern Australian species reported from Port Phillip Bay in Victoria, Encounter Bay in South Australia and Tasmania. It was recorded on *HMAS Manoora*, a vessel based in Sydney Harbour. This northern most record of *C. gaimardii* may indicate a natural range extension from the southeastern coast of Australia. It may also be the result of the translocation of *C. gaimardii* from the southern coast of Australia to Sydney Harbour via shipping. Sampling elsewhere around Sydney Harbour and along the southern NSW coast would be necessary to confirm its distribution and likely mode expansion.

N. laticaudum known from NSW and SA, was found on *HMAS Dechaineux*, at Garden Island, WA. The specimen we found was immature and less likely to have survived being transported on a ship hull, than to have originated from within Cockburn Sound. *N. laticaudum* has not previously been found on the west coast of Australia, so the colony may be localised within Cockburn Sound, most likely due to translocation via shipping. Given the distribution data for this species, a natural range expansion appears unlikely due to the large distances between Cockburn Sound and the lower east coast of Australia.

Argathona spp. are found along the NE Coast of Queensland, with many inhabiting areas close to the Great Barrier Reef. The presence of isopods from this genus on *HMAS Benalla*, a patrol boat patrolling the Northern Queensland coast, and based in Cairns, would be highly likely. With many species occurring throughout the Indo-West Pacific Ocean, and

around the coast of Australia, it is difficult to determine its origin without precise identification of the specimen.

Cirolana spp are widely distributed throughout Australian waters, with several species listed in WA. The presence of *Cirolana* sp. on *HMAS Adelaide* in WA could easily represent a native species. At this point we have not been able to identify its origin due to the large number of species assigned to Australian waters. Further analysis of the characteristics that define each of the species in *Cirolana* is required to identify it.

Cymodocella spp. have a predominately Southern Hemisphere distribution, with species recorded from southern Australian waters, and also a large number of species recorded from South Africa. A *Cymodocella* sp was found on *HMAS Sydney* in Garden Island, WA. However, comparison to species native to Australia did not produce a match, and may indicate a yet to be described species or an introduced species, possibly from South Africa, as WA is a first-port of call for much of the international shipping coming from South Africa to Australia. Further identification of this specimen will be required to determine its origin.

Ischyromene is a genus found primarily in the southern hemisphere. There are three species found in Australian waters, but the isopod found on *HMAS Warramunga* is not one of these. *HMAS Warramunga* was at Dunedin, New Zealand, when sampled again the isopod did not match any known New Zealand species. This suggests an introduced or yet to be described species.

Pseudosphaeroma spp. are found in Bass Strait, as well as New Zealand, Snares IIs, Campbell IIs, Chile and Tristan da Cunha. The species found in Australia waters is *P. campbellense*, which does not taxonomically match the specimen we found on *HMAS Darwin*, in Garden Island, WA. This specimen is likely to be an introduced or previously unknown species. Two other *Pseudosphaeroma* specimens were found on settlement ropes, situated in Garden Island, which strongly points to an established population within Cockburn Sound.

6.2 Caprellidea

The caprellid *C. equilibra* was the predominate species found in the biofouling collected from ships docked in Cockburn Sound, with very small numbers of *C. californica* also present. Other surveys conducted in that area, have recorded high numbers of *C. equilibra* throughout Cockburn Sound. This is not unexpected as the first documented record of *C. equilibra* was in 1947, and showed high numbers of the caprellid throughout Fremantle Harbour (McCain, 1965), moreover the caprellid has a temperate distribution that appears to be well suited to the waters around Cockburn Sound and has become well established in part due to its tolerance of sandy or muddy substratum.

The caprellid *C. penantis* was the predominant species in Port Philip Bay in Victoria, with low numbers of both *C. equilibra* and *C. californica*. *C. penantis* was present in very low numbers in biofouling collected from ships docked in WA and Sydney. It is 'cold

adapted', and has been recorded in Antarctic and Subantarctic islands (Keith, 1969). This would indicate that this species prefers the southern coastline of Australia. This is unusual as most intertidal and shallow water caprellids from the North Pacific occur almost exclusively in the 10-15°C temperature range, with only a few species in the 5-10°C range, with the general rule that a decrease in caprellid abundance and diversity occurs toward colder waters (Thiel, 2003). *C. penantis* prefers hard bottom substratum, which is an advantage in and around Port Philip Bay, and appears to have traits that seem advantageous to species that are able to colonise vacant but often physically rigorous habitats at unpredictable intervals (Bynum, 1978). This may explain the low numbers of *C. penantis* found in the warmer waters of Sydney and WA.

C. californica was found in small numbers on two ships docked in WA and on one ship docked in Sydney. Unlike the other caprellids found in the ship biofouling, *C. californica* demonstrates a substrate specificity for *Bugula neritina*, *Polysiphonia pacifica* and *Ulva lobata*, in decreasing order of preference. It was frequently found in samples with *C. equilibra* and once with *C. penantis*.

P. pusilla was the most prevalent species found on the local patrol boats in the Port of Cairns. Indications are, that a colony has established itself with specimens of both males and females collected from biofouling. The presence of one specimen of *P. pusilla* in WA will require further investigation to determine whether more specimens are present.

7. Conclusion

Isopods were commonly found in the fouling in the Navy ships, but not in high numbers. Most were associated with established biofouling communities of acorn barnacles, in niche areas not protected by antifouling paints. The most frequently occurring species *P. sculpta* and *S. walkeri* were taxa known from Australian ports, although thought to be introduced to Australia. Their presence on the ships supports the hypothesis that isopods have actively been translocated between ports within biofouling on ship hulls and this vector is still active. The presence of *S. walkeri* at Garden Island, WA, had not been recorded in Cockburn sound previously.

Two findings represent new distributional records for species: *S. walkeri* in Cairns, and *N. laticauda* in WA. Both findings could represent domestic translocations by shipping from other Australian ports.

The taxa that could not be identified to species may be either previously undescribed native, or non-native species introduced to Australia. The *Pseudosphaeroma* and *Ischrymene* species found, in particular, did not match any taxonomic species.

Observations in this study suggest that most of the isopods found on the Navy ships were likely to have colonised the ships from local populations in the vessel's homeports. However, this cannot be determined with certainty. What can be said is that various species of isopods are able to colonise niche biofouling on ships and survive oceanic

voyages. Biofouling on ships therefore continues to be a potential vector for isopod translocation and range extension.

Pseudosphaeroma sp and *Cymodocella* sp not from Australian waters were also reported on ships in Garden Island, as was *N. laticauda*, normally found on the south eastern coast of Australia. It appears that the areas around Garden Island have been exposed to a number of new species that have been introduced via shipping or may be undescribed species. The distribution of *P. sculpta* in this survey was not unusual given its Australia-wide distribution, so it is difficult to determine whether any further encroachments into uncolonised areas have occurred from these results.

An *Ischyromene* sp. found on an Australian ship in Dunedin, which was not native to Australian or New Zealand waters, suggests that this specimen has been translocated to New Zealand via shipping and picked up by the vessel during its stay in Dunedin, or it may be a species native to New Zealand waters, and as yet undescribed. Further study is required to determine its origin.

The presence of *S. walkeri* and *Argathona* sp found in the port of Cairns does not appear unusual. *S. walkeri* has been translocated to shipping ports as far north as Port Lucinda, and Cairns would be the next step geographically in the translocation of *S. walkeri* along the North Eastern Coast of Queensland. The *Argathona* sp has several species local to NE Queensland; its presence on boats in the Port of Cairns is not considered unusual. A closer look at the taxonomic characteristics of the specimen will be required to identify it to species level, to determine whether it is native or introduced.

The small numbers of caprellids recovered from the biofouling taken from the Navy ships indicated that this is not the preferred habitat for caprellids. The availability of suitable substratum for a caprellid on a ships hull, is affected by the physical stress generated by the movement of the vessel through water, which translates into shear stress that can damage and on many occasions dislodge long filamentous algae, and with it caprellids, reducing the number found on ship hulls.

Large numbers of *C. equilibra* were found in Cockburn Sound, indicating well-established colonies that are soundly entrenched, and responsible for the transferral of caprellids from the surrounding port onto biofouling on ships. *C. equilibra* is found right around the eastern coast of Australia from Port Philip Bay to the Port of Cairns.

C. penantis was found in Cockburn Sound and Sydney port, but in low numbers. It is quite prevalent in Port Philip Bay, where it is the dominant species of caprellid. This caprellid is 'cold adapted' and better adapted to the colder waters of southern Australia

P. pusilla is an introduced species that has colonised the Port of Cairns. It is highly likely that its translocation into Australian Waters was via commercial shipping routes, from countries such as China. The importance of finding one specimen of *P. pusilla* in Cockburn Sound WA is difficult to determine and will require further surveys in an attempt to discover whether other specimens are present.

C. californica was found in Cockburn Sound and the Port of Sydney. It has also been found in Port Philip Bay. In all of these cases, the number of caprellids was low, and points to small localised colonies along the coastline of Cockburn Sound, and stretching from Port Philip Bay along the eastern coast to the Port of Sydney.

In conclusion, caprellids appear to be adapted to and morphologically highly modified for life in a fouling community dominated by hydroids, bryozoans and filamentous algae. Many caprellid species are very unselective with respect to their substratum and they colonise a wide variety of different substrata. eg *C. equilibra*-algae, seagrasses, bryozoans, bivalves, sponges. In general, the local environmental habitat conditions such as hydrodynamics, sedimentation rate, turbidity, substratum stability, seem to be more important in determining the distribution of littoral caprellids than substratum characteristics. The geographically limiting effects that substratum once played in determining distribution, is now being eliminated by an organisms ability to 'hop a ride' on a passing ship as a result of the problems associated with the man-made effects of translocation.

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19. ABSTRACT Biofouling on ships not only impedes ship movement, but also allows species from one location to be transported to a site that it would normally not inhabit. In many cases, these exotic species have had deleterious effects on the native species, sometimes resulting in the extinction of less competitive native species. In an attempt to gain some understanding of the environmental threat posed by biofouling from vessels arriving from overseas, Defence has undertaken a survey of the biofouling present on Royal Australian Navy (RAN) Ships that have returned from overseas duties. Within the crustacean order Isopoda, several species are known to have been translocated, as biofouling, on early wooden ships. The two most common species found in the DSTO/RAN study were <i>Paracerceis sculpta</i> and <i>Sphaeroma walkeri</i> , both previously reported as introduced species and now having a wide distribution, both in Australia and world wide. Other species that were recorded in the survey were <i>Neosphaeroma laticaudum</i> and <i>Cymodoce gaimardii</i> . Some of the specimens received were too immature to allow identification to species level; these were identified as belonging to the following genus; <i>Cymodocella</i> , <i>Ischyromene</i> , <i>Argathona</i> and <i>Cirolana</i> . Caprellid species identified from biofouling samples taken from RAN ships were; <i>Caprella penantis</i> , <i>C. californica</i> and <i>C. equilibra</i> . <i>Paracaprella pusilla</i> was also identified in this survey.					